November 1998 Vol. 22 No. 11

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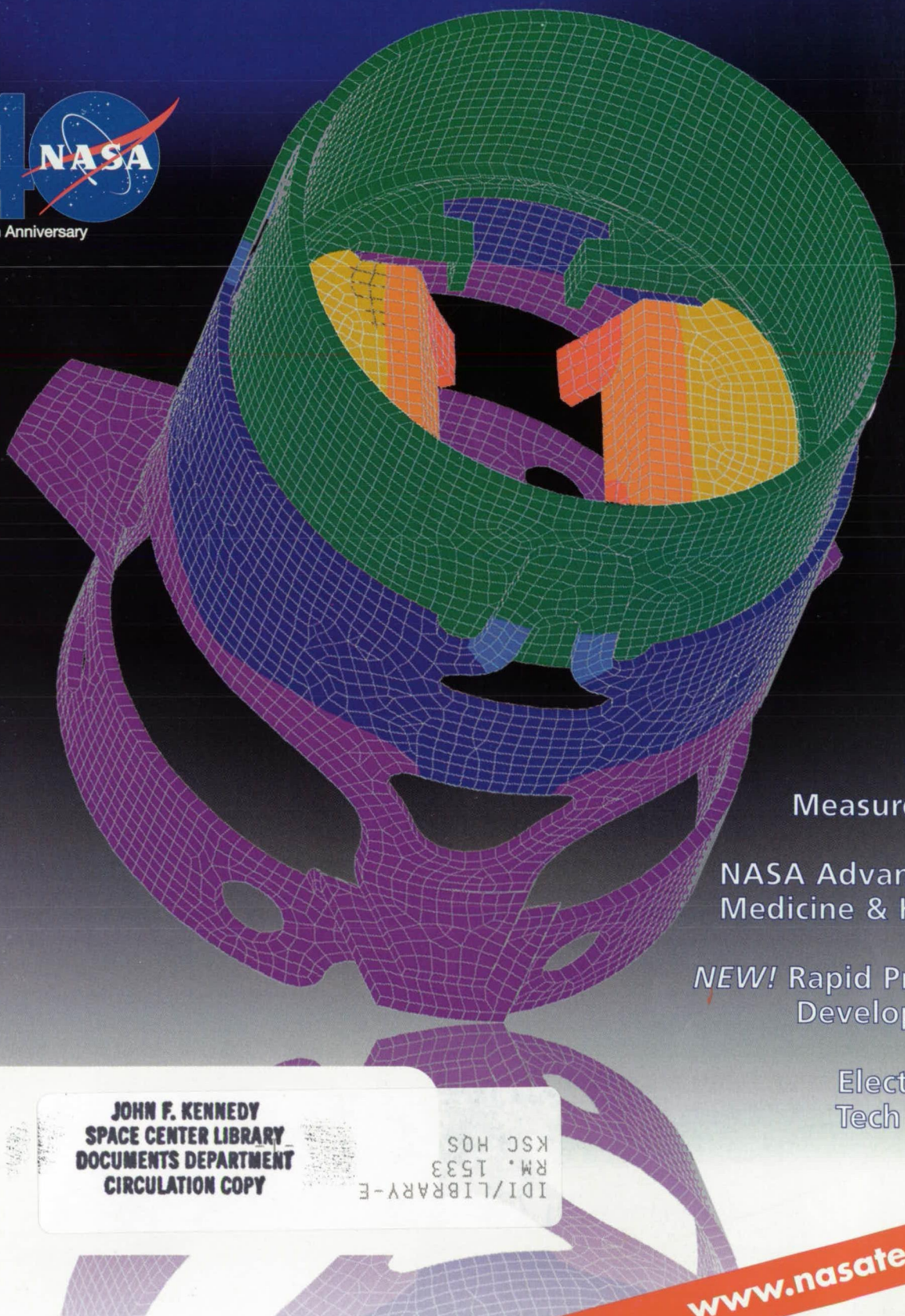

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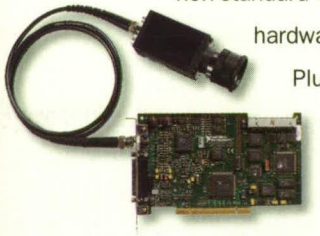

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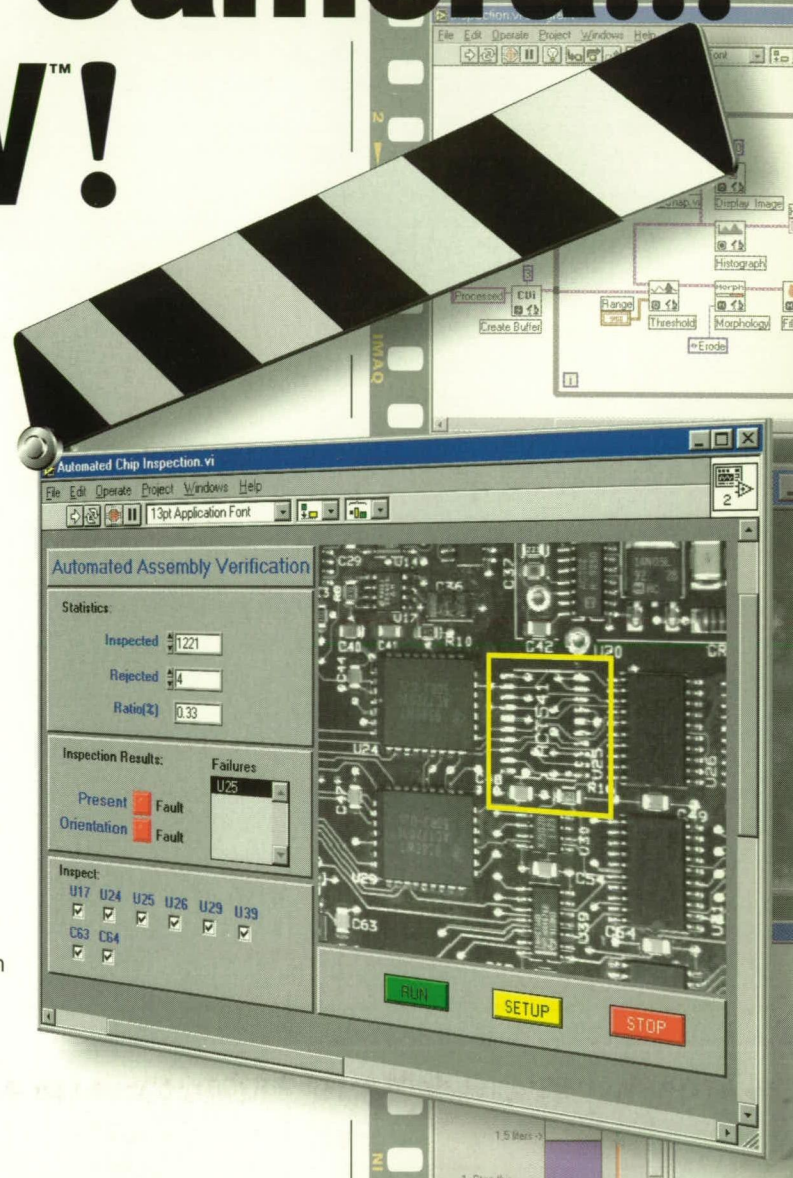

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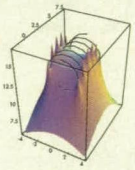

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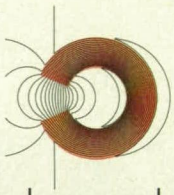

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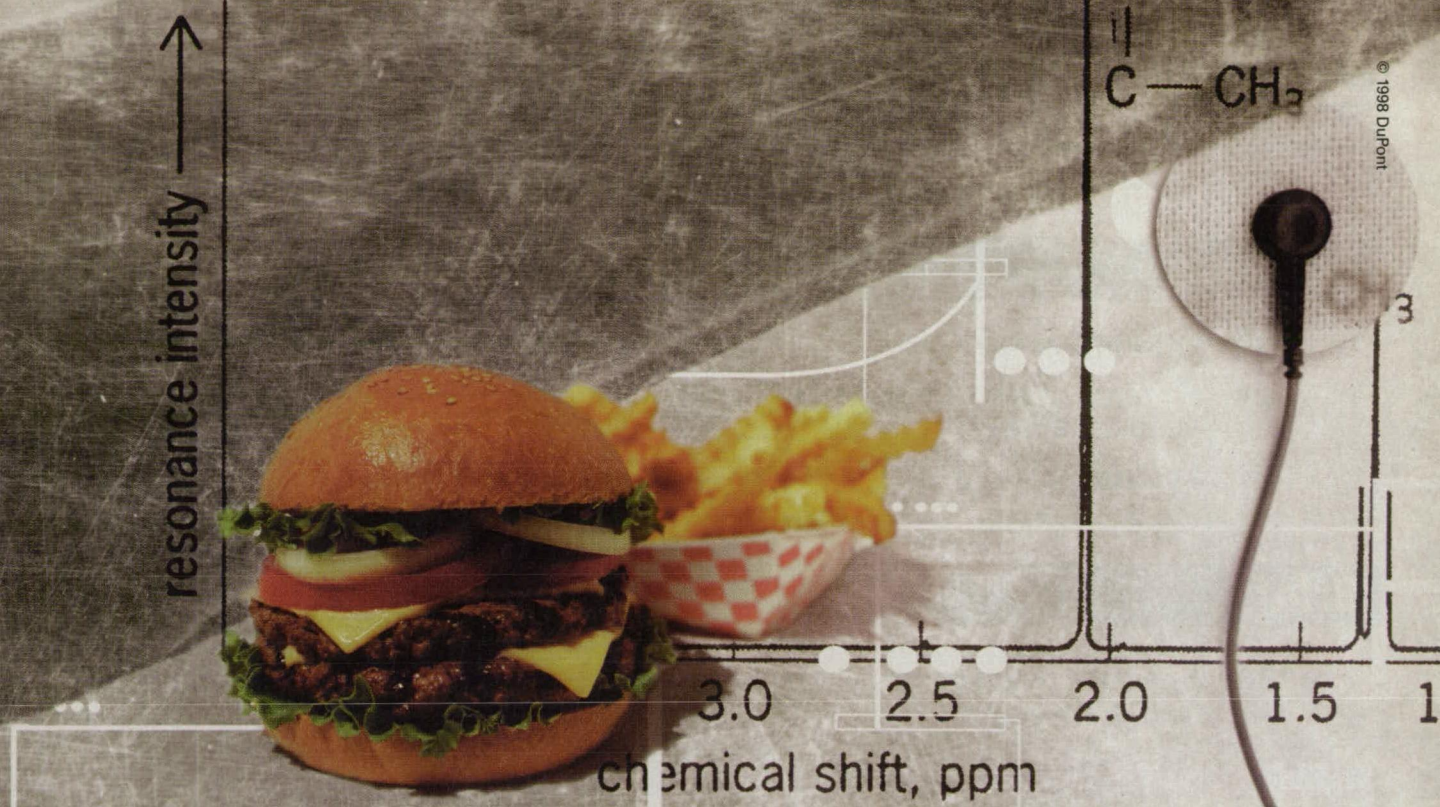
After the heart attack, your doctor recommended a better diet. Who knew it would include french fries and chocolate cake?

Guilt-free fries. Bread enriched with cancer-fighting compounds. Pork that's virtually fat free. A new generation of NMR probes built with DuPont superconducting circuits may soon help scientists create healthier, more nutritious foods.

Since its discovery a decade ago, high temperature superconductivity (HTS) has ranked as one of the greatest and most mysterious scientific discoveries of the 20th century. The ability to conduct electricity without resistance may someday make practical such marvels as trains that float magnetically in thin air, supercomputers that fit inside a shoe box and frictionless flywheels that populate the highways with electric cars.

At last, one of the promises of superconductivity is here—superconducting electronic circuitry. DuPont scientists have pioneered HTS thin film technology for laying down microscopically thin surfaces on wafers and etching circuit patterns into them. What's more, DuPont is now incorporating these HTS materials into devices and subassemblies for use in PCS and cellular communications, radar, MRI instrumentation and high gradient magnetic separators for kaolin clay processing.



As for the potential of these devices, consider nuclear magnetic resonance (NMR) instrumentation. Because superconducting sensors can produce extremely low noise receivers, NMR probes are being developed that are up to 10 times more sensitive than today's equipment. The ability to identify smaller samples with higher accuracy will allow scientists to embark on projects of much greater scope and depth. Conventional NMR has aided DuPont scientists in developing high oil corn, better tasting canola oil and high oleic acid soybeans. Imagine the radically healthier foods that may be created in the future using superconducting probes.

In communications, the advantage of sensitive receivers is equally important. DuPont offers a full foundry service for PCS and cellular components and devices based on HTS thin films such as low phase noise oscillators, ultra-high Q resonators, high-power filters, inductors and high-speed switches. HTS filters have already been successfully demonstrated in the field.

The benefits of such devices include improved call quality, extended cell site range, greater in-building penetration, lower handset transmit power and increased call-handling capacity. In fact, it may be possible to actually skip every other base station in a rural PCS system.

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Features

Briefs

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The Datavisor 80 is a full-color head-mounted display system that delivers 120 degrees of view to the user, which is comparable to seeing a 14-foot-wide screen from a distance of eight feet. The Datavisor, from n-Vision of McLean, VA, is being used by NASA to train astronauts how to walk and work in space. When looking straight ahead, the wearer sees the virtual world, piped in from a desktop control unit. For more information on the Datavisor, see the Application Brief on page 32.

(Photo courtesy of n-Vision)

How to Reduce the Number of Breast Cancer Fatalities with Advanced Engineering Software

This year, about 180,000 women will be diagnosed with breast cancer in the United States, but fewer will die thanks to improvements in early detection. A new cancer detection technique, called elastography, not only detects tumors but will also help doctors to determine whether tumors are malignant or benign. In the development of this technique, a group of scientists analyzed virtual breast tissues on the computer using the finite element analysis software of Algor, Inc. - software used to make better, safer products in a variety of industries. The research is lead by Dr. Jonathan Ophir, at University of Texas Medical School at Houston.

Breast Cancer Management

X-rays, ultrasound and physical examinations are currently used to detect tumors. Then, doctors perform biopsies to determine malignancy. Reducing the number of unnecessary biopsies is a goal in breast cancer management because the average biopsy costs between $2,000 - $3,000 and causes considerable stress to patients. Only about 20% of tumors identified by x-ray mammography are found to be cancerous when biopsied.

As a detection technique, elastography is based on the principle that different types of tissues have different stiffnesses. In the normal breast, glandular structures may be firmer than connective tissue, which is firmer than fat. Tumors are several times stiffer than healthy tissues. The medical practice of physical examination is also based on the assessment of tissue stiffness. However, the small size of a tumor and its location deep in the body prevent detection by touch. Elastography images the stiffness of tissues and tumors regardless of their location and may enable doctors to distinguish benign from malignant tumors.

How Elastography Works

To create an elastogram, two ultrasound images of the same breast tissue are taken: the tissue in its normal, uncompressed state, and the tissue when compressed. Elastography compares these to determine how the tissue moved when compressed, then converts that information into an image. Tumors are visible on an elastogram because they are stiffer than the surrounding tissue. Cancerous tumors grow in a disorganized way, resulting in variation in stiffness from one part of a tumor to another. If a tumor's stiffness is fairly uniform throughout, doctors may decide that the tumor is benign.

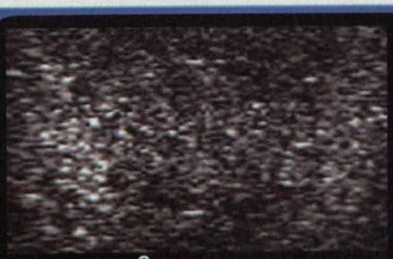
A patient undergoes x-ray mammography. Only about 20% of tumors identified by x-ray mammography are found to be cancerous when biopsied. Biopsies cost between $2,000 and $3,000 and cause considerable stress to patients. FEA helps reduce the number of unnecessary biopsies.

Using FEA to Optimize Elastography

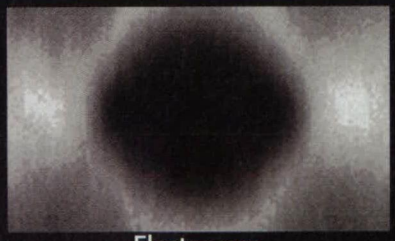
To confirm the effectiveness of the technique on different types of tumors in various locations, researchers simulated tumors with varying conditions: from a malignant tumor near the chest cavity to a cyst near glandular tissue. Researchers have already determined the material properties of real tissues including muscle, fat, glandular tissues and various types of tumors by testing tissue samples. For each hypothetical placement of tissue, researchers used Algor's Superdraw III to create a computer model of the tissue in its normal state. The model was compressed about one percent and analyzed with Algor's linear stress analysis software.

Researchers viewed displacement and strain results to predict what an elastogram of that tumor/location combination will look like. Researchers also performed real-life testing on gelatin test objects. Comparing results of the finite element analyses with elastograms of test objects enabled researchers to optimize the procedure and develop new software algorithms that better display strain.

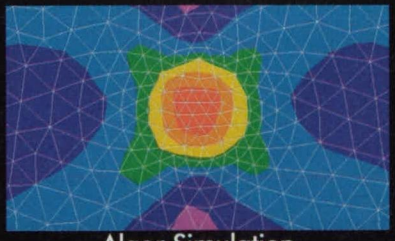
Although still in an early stage, the initial results of clinical work are promising. Researchers have identified several possible indicators for distinguishing between benign and cancerous tumors. In the future, the researchers will try using elastography to detect and evaluate other kinds of cancer, particularly prostate cancer.



Sonogram



Elastogram

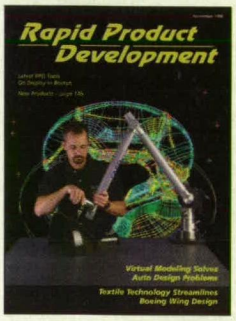


Algor Simulation

A gelatin test object contains an inclusion that has the same ultrasonic properties as the surrounding medium, but is three times harder. The sonogram (left) does not detect the presence of the inclusion, while the elastogram (center) demonstrates it well. The bright region centered on the inclusion in the elastogram is a stress-concentration artifact predicted from the Algor software simulation of the sample at a 45 degree angle (right). (*Test object courtesy of Dr. T. Hall from the University of Kansas Medical Center.*)

Contents *continued*

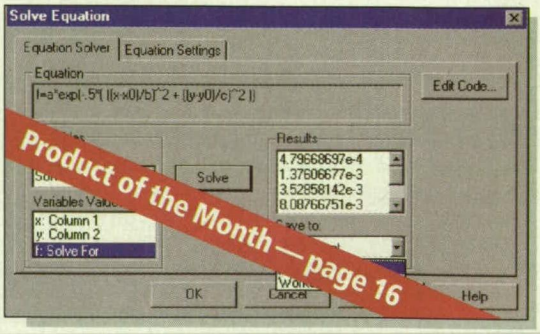
Special Supplements



On the cover:

Osram Sylvania of Hillsboro, NH, used Merlin Meshing Technology and Superdraw III software from Algor, Inc., Pittsburgh, PA, to interface their CAD system with Algor's Heat Transfer Analysis Software for this automotive light bulb component design. Osram Sylvania's automotive lighting components are activated countless times every day as drivers signal lane changes and passengers open doors. The company uses Algor mechanical engineering software to reduce the heat that passes from a light bulb, through a metal component, to the plastic lighting base. See New on Disk, beginning on page 76, for information on other advanced software programs.

(Image courtesy of Algor, Inc.)



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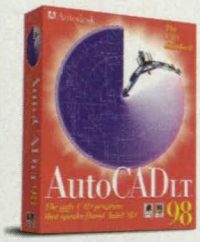

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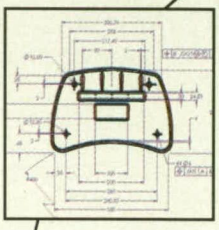

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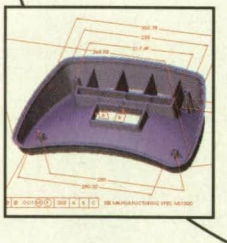

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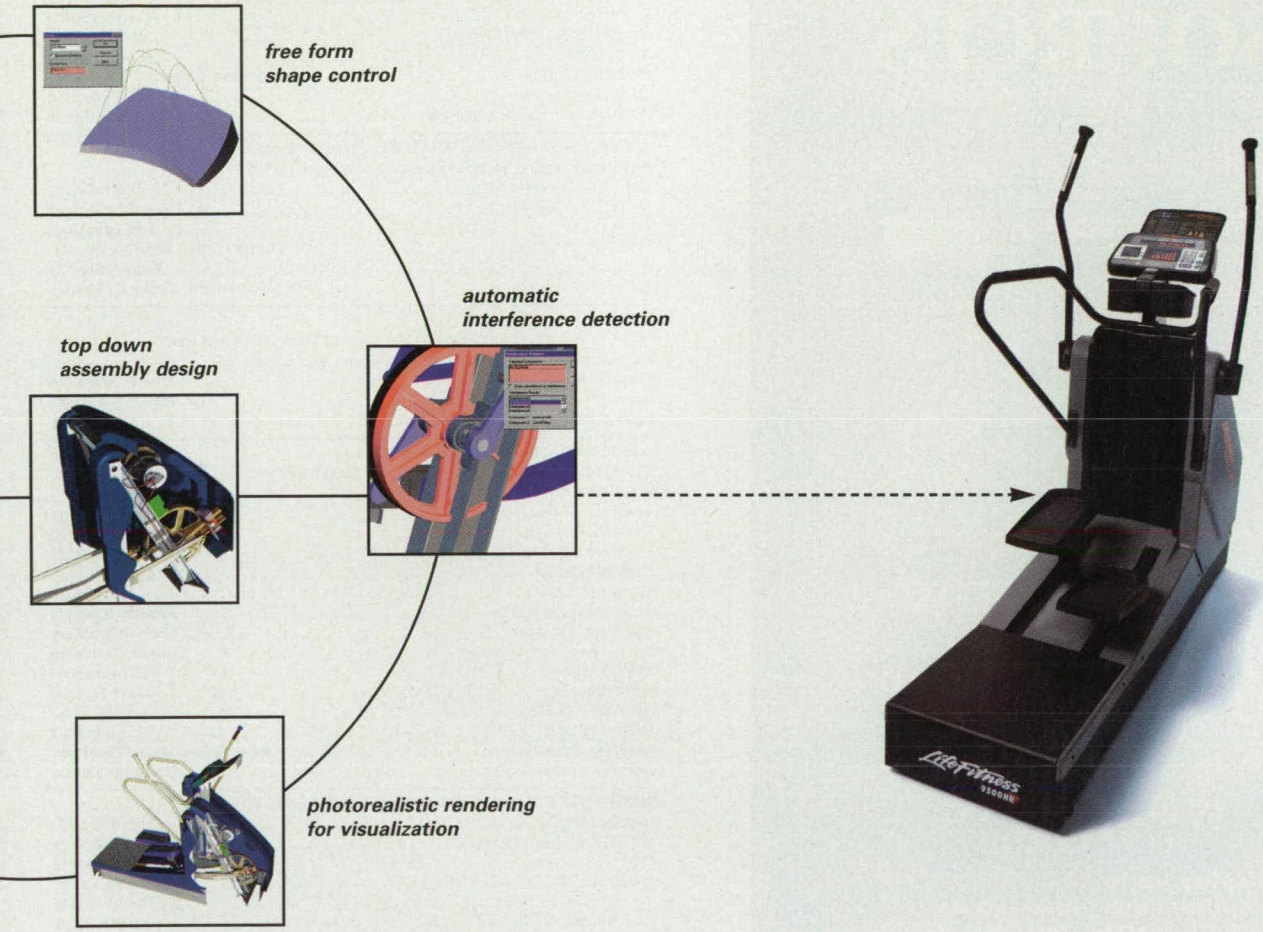

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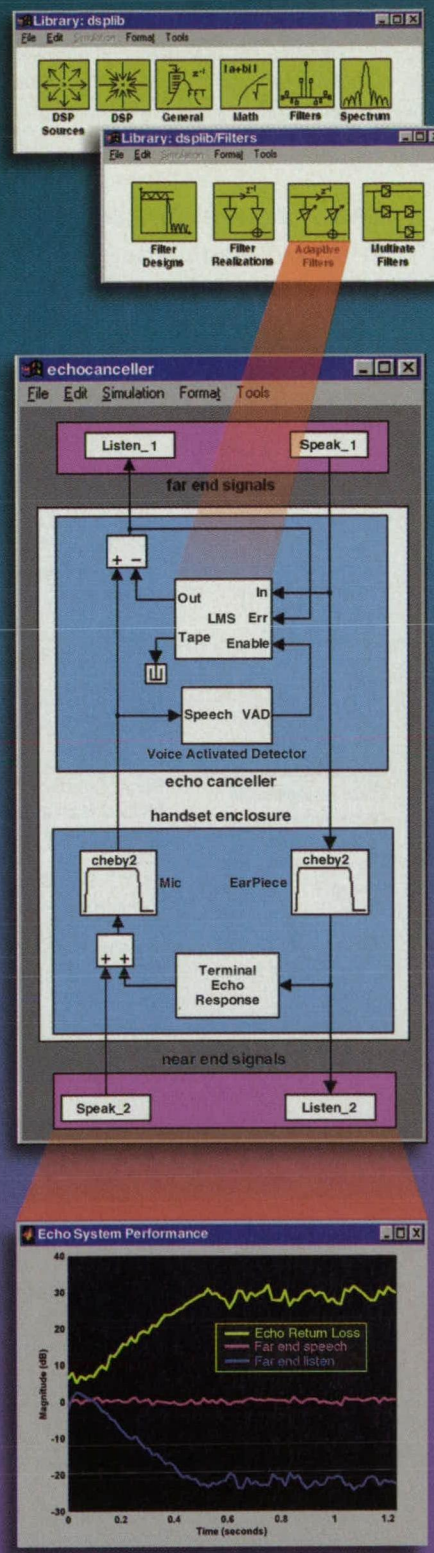

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Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
Carolina Blake
(650) 604-0893
cblake@mail.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Lee Duke
(805) 258-3802
lee.duke@dfrc.nasa.gov

Goddard Space Flight Center
Selected technological strengths: Earth and Planetary Science Missions; LIDAR; Cryogenic Systems; Tracking; Telemetry; Command.
George Alcorn
(301) 286-5810
galcorn@gsfc.nasa.gov

Jet Propulsion Laboratory
Selected technological strengths: Near/Deep-Space Mission Engineering; Microspacecraft; Space Communications; Information Systems; Remote Sensing; Robotics.
Merle McKenzie
(818) 354-2577
merle.mckenzie@ccmail.jpl.nasa.gov

Johnson Space Center
Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
Hank Davis
(713) 483-0474
hdavis@gp101.jsc.nasa.gov

Kennedy Space Center
Selected technological strengths: Environmental Monitoring; Sensors; Corrosion Protection; Bio-Sciences; Process Modeling; Work Planning/Control; Meteorology.
Gale Allen
(407) 867-6626
galeallen-1@ksc.nasa.gov

Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Dr. Joseph S. Heyman
(804) 864-6006
j.s.heyman@larc.nasa.gov

Lewis Research Center
Selected technological strengths: Aeropropulsion; Communications; Energy Technology; High Temperature Materials Research.
Larry Viterna
(216) 433-3484
cto@lerc.nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Sally Little
(205) 544-4266
sally.little@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Kirk Sharp
(228) 688-1929
ksharp@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the Regional Technology Transfer Center nearest you, call (800) 472-6785.

Joseph Allen
National Technology Transfer Center
(800) 678-6882

Ken Dozier
Far-West Technology Transfer Center
University of Southern California
(213) 743-2353

Dr. William Gasko
Center for Technology Commercialization
Massachusetts Technology Park
(508) 870-0042

J. Ronald Thornton
Southern Technology Applications Center
University of Florida
(904) 462-3913

Gary Sera
Mid-Continent Technology Transfer Center
Texas A&M University
(409) 845-8762

Lani S. Hummel
Mid-Atlantic Technology Applications Center
University of Pittsburgh
(412) 383-2500

Chris Coburn
Great Lakes Industrial Technology Transfer Center
Battelle Memorial Institute
(216) 734-0094

NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

Carl Ray
Small Business Innovation Research Program (SBIR) & Small Business Technology Transfer Program (STTR)
(202) 358-4652
cray@mail.hq.nasa.gov

Dr. Robert Norwood
Office of Aeronautics and Space Transportation Technology (Code R)
(202) 358-2320
rnorwood@mail.hq.nasa.gov

John Mulcahy
Office of Space Flight (Code MP)
(202) 358-1401
jmulcahy@mail.hq.nasa.gov

Gerald Johnson
Office of Aeronautics (Code R)
(202) 358-4711
g_johnson@aeromail.hq.nasa.gov

Bill Smith
Office of Space Sciences (Code S)
(202) 358-2473
wsmith@sm.ms.ossa.hq.nasa.gov

Roger Crouch
Office of Microgravity Science Applications (Code U)
(202) 358-0689
rcrouch@hq.nasa.gov

Granville Paules
Office of Mission to Planet Earth (Code Y)
(202) 358-0706
gpaules@mtpe.hq.nasa.gov

NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

Dr. Jill Fabricant
Johnson Technology Commercialization Center
Houston, TX
(713) 335-1250

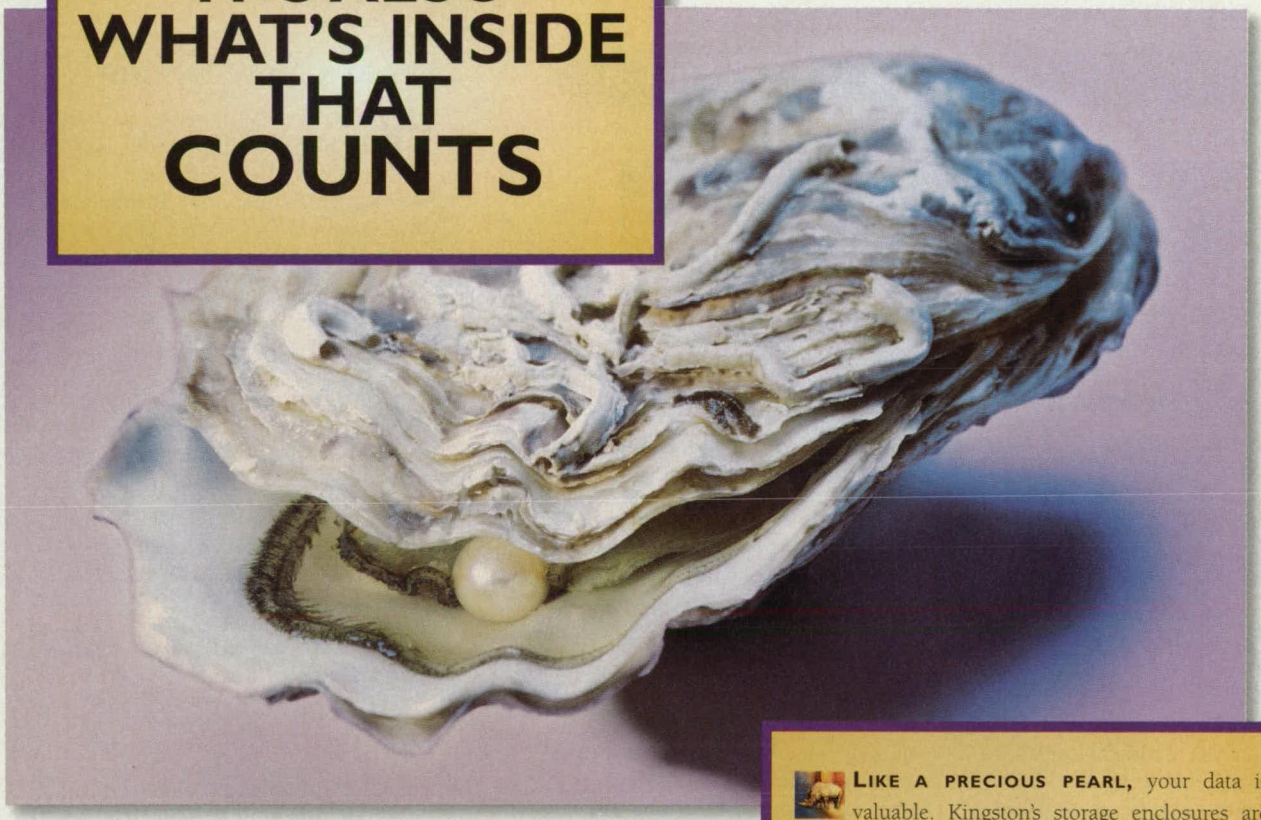
Wayne P. Zeman
Lewis Incubator for Technology
Cleveland, OH
(216) 586-3888

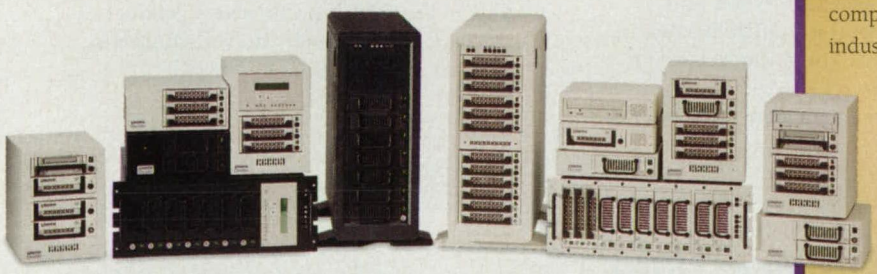
Joe Boeddeker
Ames Technology Commercialization Center
San Jose, CA
(408) 557-6700

Dan Morrison
Mississippi Enterprise for Technology
Stennis Space Center, MS
(800) 746-4699

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.

IT'S ALSO WHAT'S INSIDE THAT COUNTS





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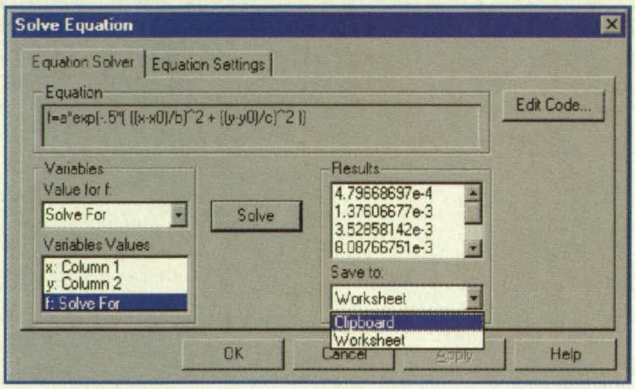
PRODUCT OF THE MONTH



SPSS, Chicago, IL, has introduced SigmaPlot 5.0 scientific graphing software for automated graphing and data analysis. The software enables users to create exact 2D and 3D technical graphs. New features include a macro language that can be used to create custom menu choices and dialog boxes, acquire and graph data in real time, or execute analytical methods; a Function Plotter Wizard that plots over 100 built-in functions by selecting a function and specifying the parameters and range; and a Function Solver Wizard that solves both built-in SigmaPlot equations and user-defined equations. A new data worksheet enables faster data operations and the ability to work with data sets containing over one billion data points. An improved notebook and compatibility with Excel, Word, and PowerPoint for Office 97 also are provided. The software runs on Windows 98.

For More Information Circle No. 759

What's New Online

What's new is our streamlined LEADnet online reader service program, which now appears under the heading "Free Product Information" at **www.nasatech.com**. Now, you need only register once. Each time you return, just provide your e-mail address for hassle-free service. In addition, one page now contains all the information you need to order advertiser information by: a) category, b) advertiser reader service number, or c) individual advertiser name. You also can link to the web sites of the advertisers from which you've requested information. Be sure to visit **www.nasatech.com** for this and other reader-friendly features.

We Want Your Vote!

It's that time of year again. Our December issue will include your Readers' Choice Product of the Year ballot — your opportunity to vote for the most innovative product of 1998. Cast your vote, and you could win some valuable prizes!

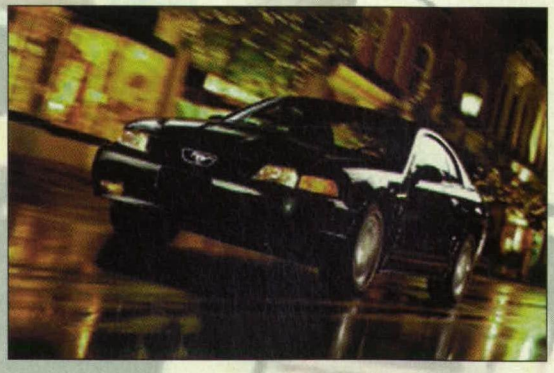
A Chip Off the NASA Block

Ford Motor Co. has licensed from NASA's Jet Propulsion Laboratory an artificial intelligence technology that Ford will install in its automobiles in the next three years. Once installed, the technology will represent the first significant change in automobile computers since they were introduced in the 1970s.

NASA scientists designed a computer chip that contains the technology, and Ford is looking for a private company to manufacture the chip. According to Ken Marko, Ford's project manager, the "cost of the manufacture will be minimal, so it will not raise the cost of an automobile." Ford's use of the chip is the beginning of what JPL sees as a huge commercial market for inexpensive neural networks, which process information simultaneously and quickly.

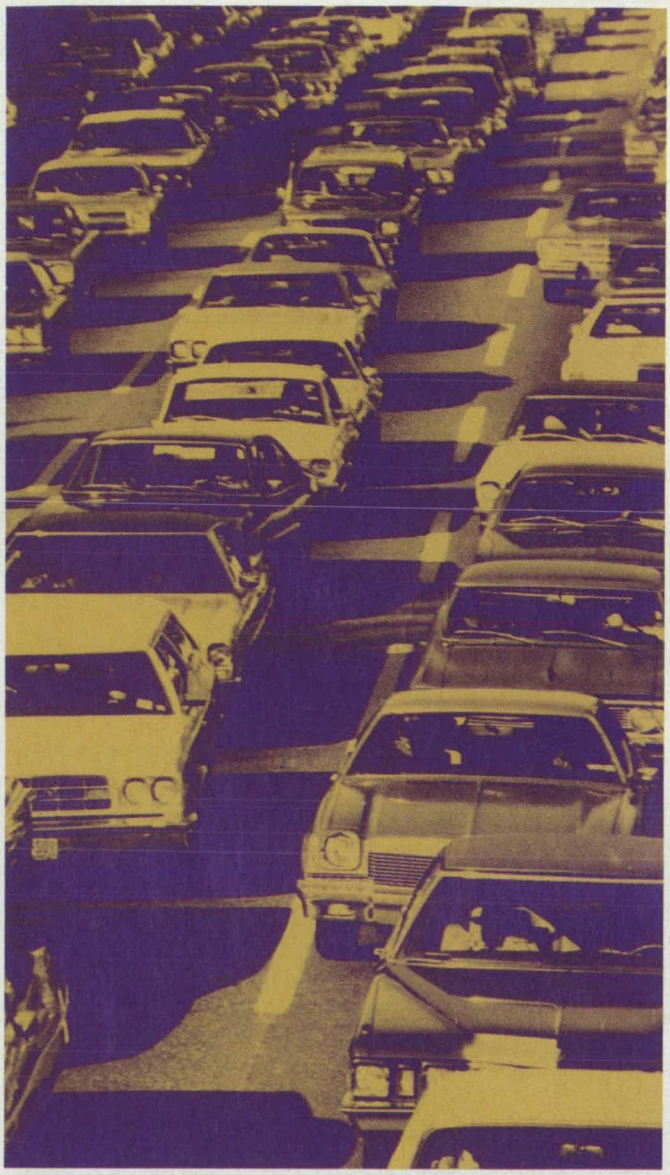
Ford will employ the chip as a virtual sensor to measure cars for air emissions. The chip will perform onboard diagnostics to make sure major systems are working properly. That information will enable Ford to estimate the composition of air emissions and meet mandatory standards in the Clean Air Act. "In the future we plan to have the chip regulate the air-fuel mixture in the car, maintain a certain engine speed, and other tasks," Marko said.

In the early stages of development, JPL scientists told Ford it would be very difficult to adapt their technology to Ford's task. "But they said they could do it and they did," according to Marko. Ford designed the methods to empower the chips to perform, while JPL developed the hardware. Said Marko, "About a year into the project, we knew we had something worthwhile."



For more information, contact Tom Hamilton of JPL at 818-354-7344, or Ken Marko of Ford at 313-390-1379.

WHAT DO *you* DO WHEN *everyone* ELSE HAS *the* SAME DEADLINE?



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Reader Forum

Reader Forum is devoted to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a specific technical problem, or an answer to a question that appeared in a recent issue, send your letter to the address below.

We are looking for a process/material to hard-coat the 2" diameter bore of aluminum cylinders. The required microhardness is 55-60 RC; required surface finish is Ra 20 µinch; and it must have good wear resistance and a cost comparable to the hard anodizing process. We currently apply hard anodizing, but this method requires a honing operation, which we would like to eliminate. Thank you.

Jan Filipecki
Gast Manufacturing
jan-filipecki@gastmfg.com

I am always looking for innovative things we can use in our business. We found information on global positioning satellites very early because of NASA Tech Briefs. *It helped us greatly in locating spots in the middle of swamps. Thanks.*

General Manager
Utility/DC

(From our online Reader Forum:)

I am in search of S-N plot for Nitronic 40 stainless steel bar that has been cold-reduced 60% (finished sizes are 3/8", 3/4", and 15/16" diameter). I have not been able to locate such information. Any help would be appreciated.

Bob Garrison

I would like any information available about flywheel storage applications with regards to utilities. I have been studying variations of energy storage for off-peak hours. There is currently an energy crisis in our area during peak load hours, and I have a feeling it is going to get worse. Thanks.

Harold Green

*(**Editor's Note:** Harold, a company that was profiled in the September issue's coverage of NASA's 40th Anniversary (page 22) called SatCon Technology Corp. of Cambridge, MA, has developed flywheel energy storage products for a number of industries, including utilities. They can be reached at 617-661-0540.)*

Post your letters to **Reader Forum** on-line at: **www.nasatech.com** or send to: Editor, *NASA Tech Briefs*, 317 Madison Ave., New York, NY 10017; Fax: 212-986-7864.
Please include your name, company (if applicable), address, and phone number or e-mail address.

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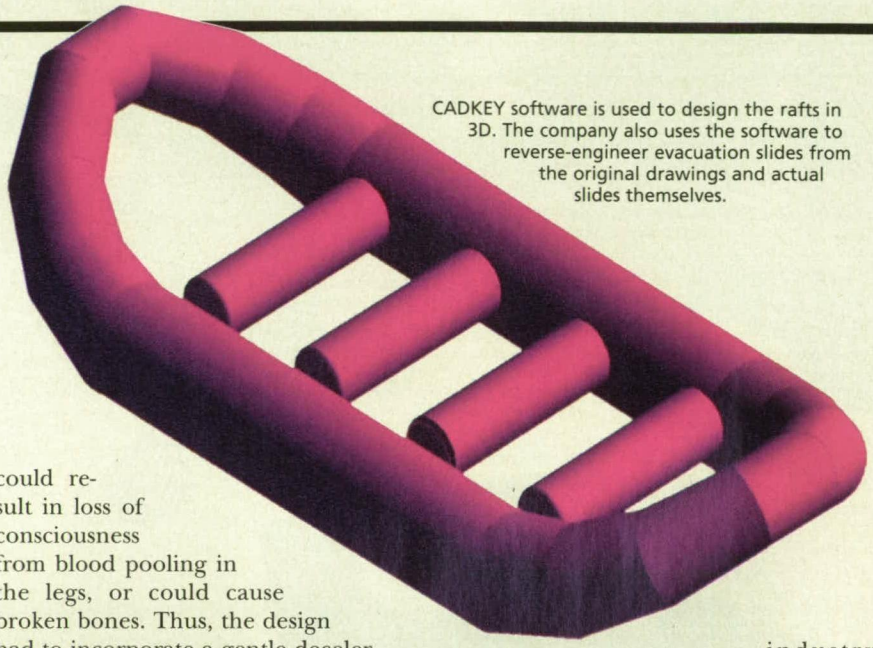

CADKEY software is used to design the rafts in 3D. The company also uses the software to reverse-engineer evacuation slides from the original drawings and actual slides themselves.

Whitewater rafting conjures up images such as swift-moving wild rivers, rafts crashing against jagged rocks, and paddlers experiencing the ride of their lives. Around the world, people are assaulting their favorite rivers with a new breed of raft. Beyond the thrill of the sport there exists expertise and technology in the creation of rafts from Colorado Headwaters, a commercial raft manufacturer in Denver.

Chris Pearson III, co-founder of the company, was uniquely qualified to enter this business. Pearson has been designing, manufacturing, testing, and marketing inflatable products since 1968. His career began designing life rafts and escape slides for commercial airlines. This background would prove to be the launching pad for two high-profile government projects, including one for NASA as the developer of the emergency escape slide for the Space Shuttle.

NASA recognized the need for an evacuation slide after the Challenger disaster. Pearson won the Space Shuttle evacuation slide bid in 1987 from OEA Aerospace, the selected contractor to NASA for the project. Pearson developed slide geometry based on the same requirements used for the commercial jet industry, with one major difference. Airline evacuation slides are designed to evacuate many people from an aircraft in less than 90 seconds with half the doors blocked. The design also requires that evacuees land on their feet and walk away quickly.

Design of the shuttle slide, however, required solving a different set of problems. Specifically, shuttle astronauts would be required to evacuate the vehicle after a space mission, before their bodies have a chance to re-adapt to gravity. A hard, standing landing likely could result in loss of consciousness from blood pooling in the legs, or could cause broken bones. Thus, the design had to incorporate a gentle deceleration to a sitting position so astronauts could stand up slowly or even crawl away. Pearson did not have the advantage of computer-aided design software in those designs, so the patterns had to be drawn and cut by hand.

Pearson's government experience also included devising an inflatable flotation system for the 70,000-pound Bradley Fighting Vehicle. Another accomplishment was the research and testing of inflatables for the U.S. Army at the U.S. Naval Academy Hydrodynamics Lab in Annapolis, MD. Early in his career, he even co-founded Maravia Corp., a manufacturer of white-water rafts that is still in business today.

Drawing on his previous NASA and government experience, Pearson founded Colorado Headwaters, which stormed onto the river-running scene with unique design capabilities and the strongest raft outside the military market.

Into the White Water

In the late 1980s, Pearson custom-built a 14-foot, self-bailing whitewater raft for a friend to use on weekend trips around the Colorado mountains. During the outings, Pearson's friend was approached by other rafters and outfitters to inquire about the manufacturer of the raft. Many of the people mentioned that if Pearson were to build more boats, they would purchase one. "From this response, I felt encouraged to start building rafts. As the defense industry was taking a new direction, it was time to try something different," said Pearson. "In 1993, I joined forces with my neighbor, Dan Vork, and incorporated Colorado Headwaters."

Pearson's original raft was used as the prototype design. During the 1993 rafting season, Colorado Headwaters built 15 rafts and demonstrated them to outfitters around Colorado. As a result, Pearson accumulated suggestions and went back into development for further refinement of the design. According to Pearson, "After 120 rafts were built, we made great headway in achieving an impact on the industry through our design innovations, which included a patent application."

Colorado Headwaters rafts are produced exclusively of a 1050-deiner, ballistic woven nylon fabric coated with a specially formulated neoprene rubber that provides long-term service without becoming porous. Pearson explained that after assembly, the boats are sprayed with a highly abrasion-resistant urethane coating that provides maximum protection. A similar fabric has been used in the manufacture of a flotation collar for armored tanks and was selected for its toughness and durability. The ballistic woven material was developed to military specifications and put through rigorous testing. One test involved stretching the fabric to just below break strength, then a round of ammunition was fired into the material. Once a projectile pierced the fabric, it left a hole, but did not propagate.

Founder Chris Pearson III's experience in designing Space Shuttle evacuation slides for NASA, as well as escape slides for commercial airlines, led to Colorado Headwaters and its technologically advanced whitewater rafts.

"The strength of material is significant for river rafting, especially if there are many passengers aboard," said Pearson. "Our rafts are designed with several air chambers. If a raft is actually punctured by a rock, the material does not continue to tear. The other air chambers keep the raft afloat until the outfitter can guide the raft to the riverside and make the proper repairs."

Pearson was involved in the testing and research of inflatables while at the U.S. Naval Academy Hydrodynamics Lab. From this experience, he said, "I could apply subtle design changes to reduce drag coefficients that enhance our product's performance. When you design evacuation slides and lifecraft for commercial airlines, emphasis is placed on light weight and durability."

Automating Product Development

In order to offer customization to their customers, Colorado Headwaters began looking for a way to automate their processes. The procedure of designing a raft, as well as creating and cutting patterns, was incredibly tedious and time-consuming. This method would take 12 to 15 hours of geometric layout. When laying out patterns for a larger boat design, striking arcs 22 feet in length was a painstaking task. It was for this reason that the company would only construct half of a model for a prototype. And there could be two or three iterations to get a final design.

"We began the search for a CAD solution to meet our needs. While at a fabric convention in Denver, we observed an exhibitor using CADKEY® (3D mechanical design software from Baystate Technologies, Marlborough, MA) to create 3D models, then flattening the part to derive patterns," said Pearson. A demo of CADKEY was performed that focused on Pearson's application, modeling a section of the raft in 3D. According to Pearson, "We merged my traditional method of designing inflatables with CAD techniques and principles. We completed a full three-dimensional raft."

"When you design lifecraft for commercial airlines, emphasis is placed on light weight and durability."

—Chris Pearson III
Co-founder
Colorado Headwaters

Pearson said that using CAD technology has changed the way his company does business, reducing a 12- to 15-hour process to two hours. Colorado Headwaters also has implemented their final phase of automation — a large-format plotting/cutting machine for producing patterns in-house.

Return to the Shuttle

Chris Pearson recently came full circle back to the Space Shuttle. Colorado Headwaters won a bid for the redesign of the Space Shuttle evacuation slide in September 1997, again from OEA Aerospace. It is necessary to replace the slides as the design lifespans are nearing the scheduled replacement dates. The computerized marking and cutting process allows Colorado Headwaters to precisely cut the giant slide pieces and hold pattern tolerances to 0.006", a contrast to the 1/8" tolerance for the original handcrafted version.

Pearson's experience with the aerospace industry brought a wealth of experience to Colorado Headwaters that was leveraged to conquer whitewater raft manufacturing. Now, the CAD and automation technology they have implemented in the past five years has been put to strategic use in the Space Shuttle project. The company is also diversifying their business and breaking into other new markets — high performance motorized craft and government contracts.

The company is currently targeting outfitters worldwide. There are 2000-plus outfitters in the US alone. With the implementation of a successful marketing strategy and CAD technology, the company's size has doubled, and they have moved into a new 18,000 square foot facility. The entire product line of Colorado Headwaters is designed and manufactured in the US.

For more information, contact Chris Pearson III of Colorado Headwaters at 2605 W. 7th Ave., Denver, CO 80204; Tel: 303-592-7150; Fax: 303-592-7152; e-mail: chrafts@idcomm.com


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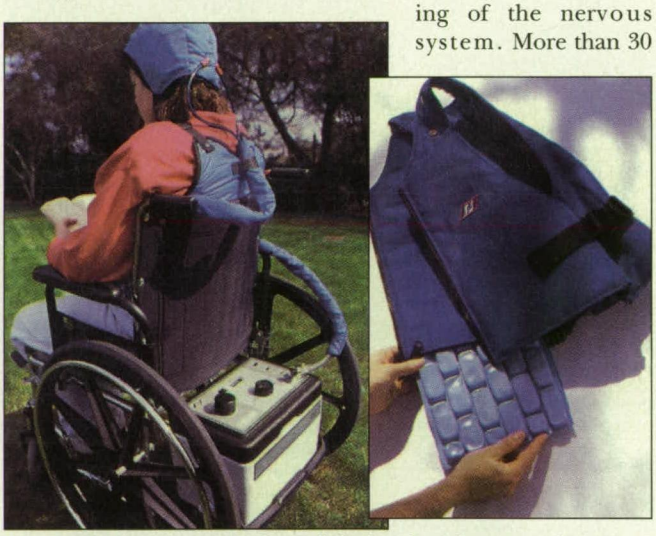
This month, in our year-long celebration of NASA's 40th Anniversary, we take a look at successful spinoff products and new applications of NASA technologies in the Medical and Health areas.

1960s

A "Cool" Innovation

Multiple sclerosis (MS) is a chronic, progressively disabling disease of the central nervous system that strikes its victims in the prime of life. Wasting of the nerves is caused by loss of a body substance called myelin. This can affect thought processes, vision, dexterity, balance, and sensation. Myelin forms a coating around the nerves like insulation, allowing signals to be conducted through the nervous system. Its absence bars proper functioning of the nervous system. More than 30 years ago, it was discovered that by cooling the body, a dramatic improvement can be seen in MS symptoms. Conduction can be temporarily restored to demyelinated nerves by cooling the body's core temperature only one degree Fahrenheit. Therefore, doctors often use cold showers, pools, and air conditioning to lower body temperatures of MS patients. But such treatment can be uncomfortable, and patient immersion in a pool can sometimes be self-defeating. Body mechanisms such as shivering and constriction of blood vessels often work to prevent a drop in core temperature.



LSSI's Mark VII cooling/control unit (left photo) can be mounted on a patient's wheelchair; the unit feeds fluids to the cool suit through an umbilical tube. The photo at right shows an alternative type of vest cooled by a quick-change ice cartridge.

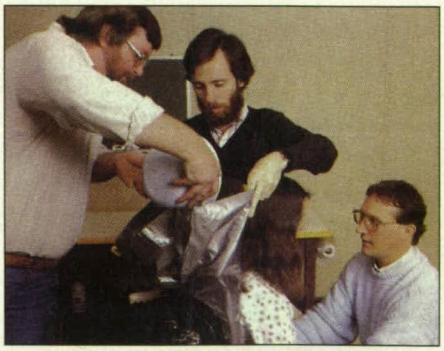
But many patients are now benefiting from a body cooling technique that does not require immersion, induce shivering, or cause blood vessel constriction. It involves using a "cool suit," previously known as the Mark VII MicroClimate® Medical Personal Cooling System. The MicroClimate technology, developed by Life Support Systems Inc. (LSSI) of Mountain View, CA, had its origin in a 1968 NASA development program at Ames Research Center that produced a spacesuit undergarment for cooling astronauts on the surface of the moon or during extravehicular walks outside the spacecraft. The system circulated a fluid, cooled by a heat exchanger and delivered by a battery-operated minipump, through a network of tubes in the garment. In 1980, LSSI was founded to pursue commercial uses for the technology.

Similarly, the updated suit consists of a head cap and torso vest. The system includes a fixed or portable control console, a cooling unit, and a pump, which circulates a water-based fluid, cooled to about 50°F, through veins or tubes in the vest and cap. It can lower a patient's core temperature 1°F in 30 to 40 minutes, with improvement in symptoms that continues for two to four hours after a cooling session. It is used to treat symptoms of MS and other illnesses where temperature regulation can be beneficial, such as spina bifida and cerebral palsy.

Unfortunately, the system is not a cure, nor does it help all MS patients. It has, however, helped many by improving their quality of life. The Multiple Sclerosis Association of America (MSAA) has bought and placed cool suits in more than 50 MS research care centers in the U.S., and it is estimated that, through such centers, more than 100,000 MS patients will be able to get cool suit treatment.

A Cushy Idea

One of the most widely used NASA spinoffs began 20 years ago at Ames Research Center, where a research program was conducted to improve crash protection for airline passengers. One innovation developed by a program contractor was an open-cell polymeric foam material intended for padding in aircraft seats. The material offered better impact protection in an accident and enhanced passenger comfort on long flights by distributing body weight and pressure evenly over the entire contact area. Called "slow springback foam," it flowed to match the contour of the body pressing against it, and returned to its original shape once the pressure was removed.



Foam-In-Place Seating is produced by mixing Sun-Mate ingredients, pouring the mixture into a plastic bag — which is later used as a mold — and contouring the mold to the most therapeutic body position. The seat is then upholstered and ready for use.

Initially marketed under the name Temper Foam®, the material is used for its originally-intended application as aircraft and helicopter seats, but also has found uses in a variety of medical applications. Originally manufactured by a company formed by the contractor's employee who had invented it, Dynamic Systems Inc. (DSI) of Leicester, NC, DSI subsequently sold the rights to the original formula. DSI returned to making slow springback foam products with different formulations. The rights to the original Temper Foam were acquired by Temper Foam Inc., jointly owned by Kees Goebel Medical Specialties (Cincinnati, OH) and AliMed® (Dedham, MA).

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For More Information Circle No. 515

DVFV6NASA

DSI markets a line of orthopedic support cushions for reducing fatigue and improving circulation. Available in various sizes, thicknesses, and pressure qualities, they are sold under the names Sun-Mate, Pudgee, and Laminar. DSI's Foam-In-Place Seating (FIPS), developed for severely disabled people to slow progressive deformities and ease soreness and fatigue due to long periods in wheelchairs, is a process wherein liquid Sun-Mate ingredients are mixed, poured, and contour-molded to the individual's body and chair.

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1970s

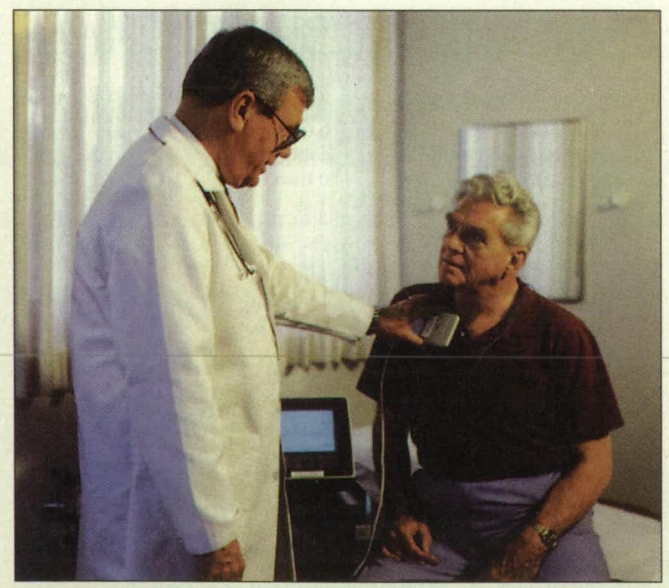
Keeping Pace

In the 1970s, Johns Hopkins Applied Physics Laboratory, NASA, and Pacesetter Systems of Sylmar, CA, developed a device later called Trilogy™ — a cardiac pacemaker that provides doctors with extensive programming capabilities, and detailed information on the patient's health and performance of the system. Introduced in 1995, Trilogy is the fourth generation of the original unit.

Pacesetter brought to the commercial market three advances based on the original collaboration in the late 70s. These were the first rechargeable, long-life pacemaker battery, based on spacecraft electrical power system technology; the first single-chip pacemaker, born out of space microminiaturization technology; and the first pacing system to utilize bi-directional telemetry, the NASA-developed technology for two-way communication with satellites that provided a means for doctors to communicate with an implanted pacemaker and program it without surgery.

In 1979, Pacesetter produced the first commercial bi-directional telemetry pacing system that would lead to their position as a world leader in the large bradycardia (slow heartbeat) market. The new system features a microprocessor that allows more functions to be automatic; a unit can adjust many of its settings on the basis of information it gathers about heart function.

Originally part of Siemens AG, Pacesetter became in 1994 St. Jude Medical, Cardiac Rhythm Management Division.



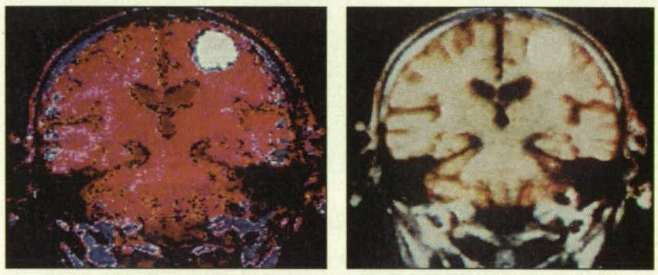
A physician checks a patient's Trilogy pacemaker.

1980s

The Human Body's "Window"

Nuclear magnetic imaging (NMR) was an experimental technique in the 1980s for viewing the inner parts of the human body. Instead of x-rays, NMR employed a magnetic field and radio waves to create body images from which radiologists could extract diagnostic information. It also was non-evasive, and unlike x-rays, could penetrate bone. NMR images provided a vast amount of anatomical and physiological information.

In the early years of its development, however, a radiologist was required to analyze 50 or more images to make a proper diagnosis of a complex problem. Dr. Michael Vannier, a professor of radiology at Mallinckrodt Institute of Radiology, Washington University Medical Center, in St. Louis, MO, employed satellite image enhancement techniques to overcome this problem. Serving previously as a NASA engineer, he was familiar with such



The image at left is a computer-processed color composite of an NMR head scan, showing a brain tumor (white area near the top). The image on the right shows how the enhancement process created a "theme map" in which each color corresponds to a different type of tissue, with the tumor sharply defined.

techniques. Vannier recognized the similarities between NMR imaging and the space technique of Earth resources imaging, in which the NASA-developed Landsat satellite takes electronic pictures in several segments of the light spectrum. Its detectors recognize "signatures" of various Earth features such as crops, water, and forests, and send the information to ground stations in a voluminous flow of data. Using NASA's computerized image processing technology, the vast amount of raw data can be analyzed easily. A computer program analyzes the data, sharpens the contrast, eliminates the confusing detail, and produces images in which the various features appear in different colors.

Vannier contracted NASA to see if the Landsat processing techniques could be applied to medical imagery. With the help of Bob Butterfield, manager of technology integration at Kennedy Space Center, and Douglas Jordan, engineering manager of the Remote Sensing and Image Processing Laboratory at the University of Florida, Vannier had a number of NMR scans processed by a computer program at the Florida lab. The program processed the images just as it would the Landsat images, combining multiple black-and-white images into a single, realistically colored composite picture. Said Vannier, " These pictures look real, just as if you lifted a slice right out of the human body."

The trio took the research a step further and learned how to make "theme maps" of the human body. In Earth resources observation, Landsat signature data is processed to create one thematic image; for example, one that separates wheat fields from all other crop areas. For medical imaging, the computer program searches the NMR images for a signature of interest to the radiologist — such as a blood clot — and colors any area that has that particular signature.

By incorporating these NASA satellite imaging techniques, the widely-used modern magnetic resonance imaging — MRI — technique was born.

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• AC amps	1μA – 3A	1μA – 3A	100pA – 2.1A	100pA – 2.1A

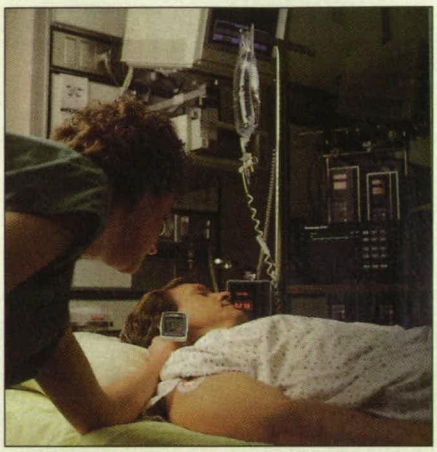
For More Information Circle No. 534

1990s

A Faster Thermometer

Introduced to the commercial market in 1991, the Diatek Model 7000 aural thermometer employs infrared technology to get an instantaneous reading. Co-developed by Diatek Corp. of San Diego, CA, and NASA's Jet Propulsion Laboratory, the project was undertaken as part of NASA's Technology Affiliates Program, which facilitates the transfer of government-developed technology to the private sector.

More than two billion clinical temperature readings are taken annually in the U.S., with about half of them in acute care hospital facilities. Diatek saw a need to reduce nursing time by providing a faster thermometer, and thought that the best route was through the use of infrared optical technology, which offered the fastest speed and greatest accuracy. It also allowed determination of body temperature by measuring the energy emitted from the tympanic membrane (eardrum) into the ear canal. This eliminated contact with mucous membranes encountered with oral or rectal thermometers, reducing the possibility of infection.



A nurse uses the Diatek aural thermometer to take a patient's temperature.

Diatek turned to NASA engineers for help with the infrared sensor. The resulting Model 7000 thermometer weighs only eight ounces, can be operated with one hand, and measures temperatures in less than two seconds, permitting measurement in newborns, critically ill, or otherwise incapacitated patients. The device has a disposable probe cover as a further guard against infection.

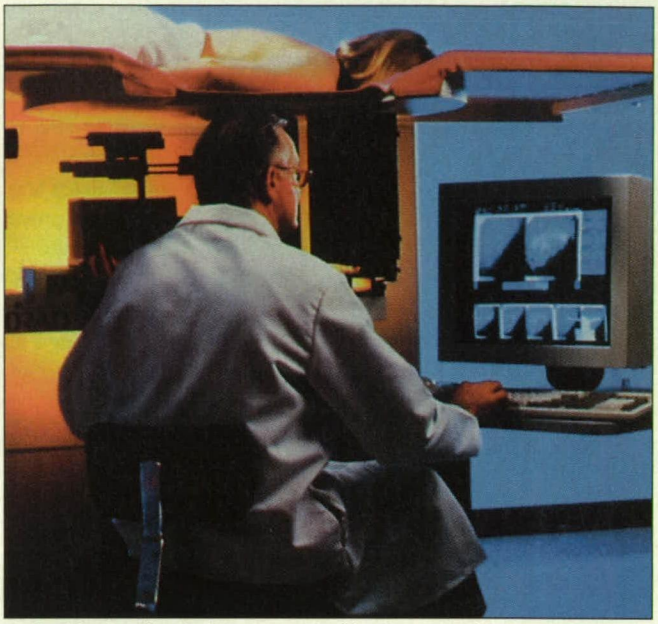
The estimated market for electronic/infrared thermometers exceeds $126 million for acute care hospitals, and a similar amount for sales to alternate health care facilities such as clinics, doctor's offices, and nursing homes.

Diatek Corp. was purchased by Welch Allyn, which markets the Model 7000 today as the Suretemp thermometer.

Better Biopsies

Charge Coupled Devices (CCDs) are silicon chips that convert light directly into electronic or digital images, which can then be manipulated and enhanced by computers. An advanced, extrasensitive CCD was developed for NASA's Hubble Space Telescope by Scientific Imaging Technologies (SITe) of Beaverton, OR. That device has contributed to a new, non-surgical and less traumatic breast biopsy technique, which is replacing surgical biopsy as the method of choice. The technique saves women time, pain, scarring, radiation exposure, and money.

Called stereotactic large-core needle biopsy, the technique is performed under local anesthesia with a needle instead of a scalpel, leaving a small puncture wound rather than a large scar. The system that makes the technique possible is the LORAD Stereo Guide™ Breast Biopsy System, which incorporates SITe's CCD as part of a digital camera system that "sees" a breast structure with x-ray vision. The system is produce by LORAD Corp. of Danbury, CT. By 1994, LORAD had produced 350 units, which were in service for biopsy procedures. Full digital breast units are available for routine mammographic examinations.



A physician studies the images acquired by the LORAD biopsy system.

The technology for the system originated at Goddard Space Flight Center, where scientists developed the Hubble Space Telescope Imaging Spectrograph. The Goddard team found that existing CCD technology could not meet the instrument's demanding requirements, so they contracted with SITe to develop an advanced, thinner, supersensitive CCD that could be manufactured at a lower cost. SITe later used NASA-driven enhancements to manufacture CCDs for the digital spot mammography market.

In the LORAD system, a special phosphor allows the CCD to convert x-rays to visible light, providing the digital camera with x-ray vision. The patient lies face-down with one breast protruding through an opening in a specially designed table. The radiologist locates the suspected abnormality with the stereotactic imaging device by taking images of the mass from two different angles. The computer then determines the coordinates of the mass and the radiologist extracts a small sample from the spot with a needle. The patient is able to walk out of the office minutes after the procedure and resume normal activities.

The procedure can be performed in a doctor's office for about $850 and is as effective as traditional surgery, which costs about $3,500. Radiologists predict that the technique will reduce national health care costs by $1 billion a year, and the potential is even broader, since the system can be used for routine (non-biopsy) breast exams.

Calling All Doctors

Since the 1970s, NASA has been in the forefront of research in the field of telemedicine — the interactive transmission of medical images and data to provide better health care for people in "medically underserved" or remote areas. NASA's interest in telemedicine developed because of the potential it holds in caring for astronauts operating beyond Earth's orbit. But today, NASA is engaged in developing new technologies that will assist in both space and Earth telemedicine applications, and is conducting demonstrations of the potential of telemedicine with local governments and the medical community.

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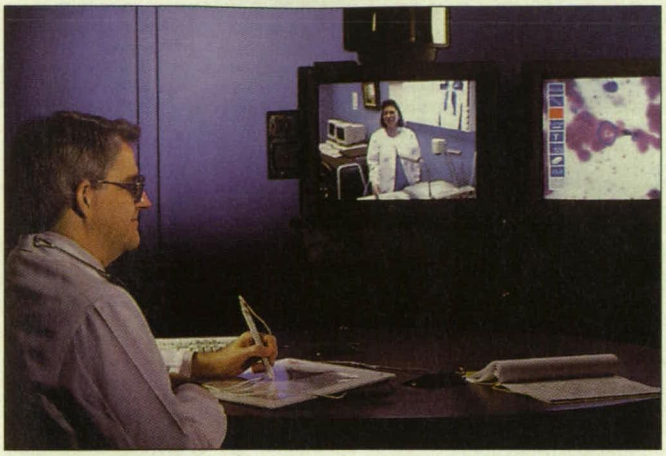

From San Antonio, Dr. James Legler views a blood slide in Harlingen, TX, by means of a video relay. Doctors in medically underserved areas are able to transmit the sounds of a patient's heartbeat or a patient's x-rays to a physician 250 miles away.

An ongoing program, started in 1995, involves the University of Texas Health Sciences Center at San Antonio (UTHSCSA), which is linked with South Texas Hospital in Harlingen, TX, 250 miles away. The South Texas area is considered a medically underserved area, with a lack of physicians and nurses trained in oncologic (cancerous) diseases. Prior to 1995, 80 pediatric oncology patients at South Texas Hospital were able to see UTHSCSA cancer specialists only once a month when the doctors visited the hospital.

Today, via the two-way audio/video link-up, the physicians can see and talk with the patients, review lab work, and consult with physicians providing the primary care at South Texas Hospital. They conduct 80 hours a month of "teleclinics" and provide instruction in pediatric oncology nursing techniques.

NASA's expertise was used in the system's design, integration, verification, and validation, as well as providing one-third of the funding to operate the system during its first year. The NASA effort was coordinated by the agency's Office of Space Access and Technology; Dryden Flight Research Center led the effort to integrate off-the-shelf computer and networking systems into the telemedicine link; and Johnson Space Center contributed networking systems and expertise.

The Texas project was made possible not only by UTHSCSA and NASA, but also by the Texas Department of Health; VTEL Corp. of San Antonio, which donated desktop videoconferencing systems, maintenance, and staff support; Sprint of Kansas City, MO, which provided high-speed fiber-optic cable links between San Antonio and South Texas Hospital; and Healthcare Open Systems and Trials (HOST) Consortium of Washington, DC, an industry-based effort to provide application of information technologies to improve health care.

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Next Month:

NASA's Contributions to Aerospace and Aeronautics

Looking Ahead ...

• The Institute for Research Inc. (IRI) and NASA's Johnson Space Center have jointly developed a new drug delivery system consisting of multilayered microcapsules that resemble miniature liquid-filled balloons several times larger than blood cells. These microcapsules are designed for delivery of anti-tumor drugs by injection into main arteries leading into solid tumors, wherein they form emboli to reduce the blood supply to the tumor and provide sustained release of cytotoxic drugs to tumor cells. The microcapsules also contain a radio-contrast oil that allows radiologists to confirm that the microcapsules have reached the target tissues. The microcapsules, formed in microgravity, are designed for "chemoembolization" of the solid without the usual side effects of systemic chemotherapy. So far, six different FDA-approved drugs have been encapsulated, including two anti-tumor drugs, an immune stimulant, antibiotics, a clot-dissolving enzyme, and an anti-nauseant. Until recently, the microcapsules could only be formed under microgravity conditions. But after several Space Shuttle flights, special formulations have been developed that allow small amounts to be formed on Earth. The system used to form the microcapsules — the Microencapsulation Electrostatic Processing System (MEPS) Flight Unit — will be available for experiments on the International Space Station.

• A portable device developed for the space program to examine how physical activity relates to bone density may serve as a way to assess a person's risk of osteoporosis. The device, developed by the Life Sciences Division at NASA Ames, provides a record of the major forces people apply to their bodies during the day by measuring and recording the interaction between the foot and the ground. This "loading" of the body plays a role in maintaining muscle and bone strength. It consists of two elements: a force sensor resembling an insole that is worn in the shoe, and a small computer carried in a fanny pack. A cable connects the two elements. The computer samples the applied force 100 times per second and stores the significant maximum and minimum forces. The force exerted on the body when it meets the ground is what keeps the muscles and bones in the lower body strong. If they are not used, they become weaker — a problem encountered by astronauts during space flight. The device will allow measurement of a person's activity to assess the risk of low bone density, allowing an exercise prescription to improve the health of older persons.

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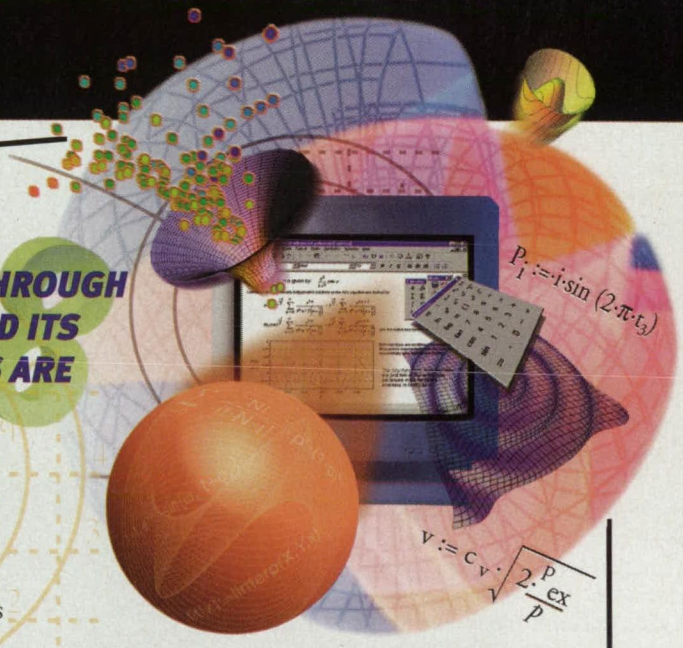

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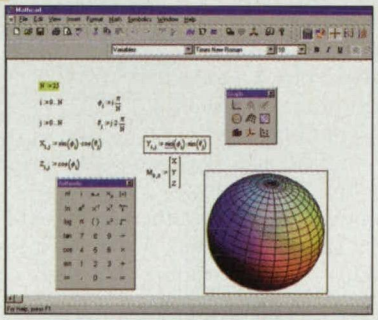

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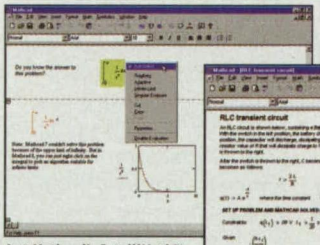

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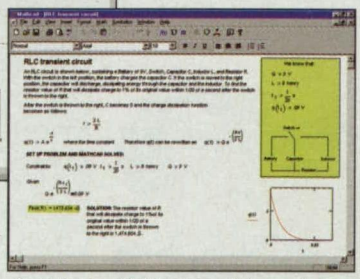

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For More Information Circle No. 527

The Virtual Gets Real

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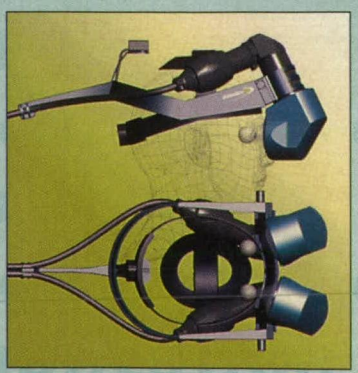
Formed in 1988, n-Vision began as an operations team at Advanced Technology Systems of McLean, VA. The team was charged with the task of miniaturizing CRTs as part of a NASA design program for the High Alpha Aircraft cockpit. The team's successful head-mounted display (HMD) project, completed in 1991, led to the Datavisor 10m, a monochrome precursor, and then to the full-color Datavisor 9c HMD. In 1994, n-Vision was incorporated as a separate entity, and introduced the Datavisor 10x before refining it into the Datavisor VGA/HiRes.

The Datavisor VGA/HiRes is a full-color HMD system consisting of optical and electronic components housed in a lightweight molded plastic shell. Weighing 56 ounces, it looks like a souped-up laptop with a head-size opening in the center. It is placed over the head, and like a regular visor, settles at ear and eye level with a balanced center of gravity. An adjustable head frame fits the device to each wearer, and adjustments for focus and interpupillary distance (IPD) are located with the hands. When looking straight ahead, the wearer sees the virtual world, piped in from a desktop control unit via cabling attached to the rear of the HMD. When other equipment is plugged in, such as a data glove, the viewer can interact with the simulated environment — move around, reach for and manipulate objects, and learn how to perform a new task.

The Datavisor 80 shown in a right front (top) and side view. Created in accordance with NASA specs and used in training astronauts, the visor provides a 120° field of view to the wearer. The boom at the rear of the headset contributes to an optimized center of gravity, balancing the device comfortably on the wearer's head.

While the VGA/HiRes unit displays up to a 78-degree field of view to the user, the new Datavisor 80 delivers 120 degrees of view, comparable to seeing a 14-foot-wide screen from a distance of 8 feet. The Datavisor 80 is being used by NASA to train astronauts how to walk and work in space.



These two views of the Pro/ENGINEER electronic product model of the Datavisor 80 show how the headset fits onto a wireframe IGES model of a human head. The design engineers even set 3D eyeballs into the head in order to align the exit pupils of the optics assembly.

The device began on a NASA wish-list, and n-Vision took up the challenge of providing NASA with the HMD they desired. "You want the most field of view and the highest resolution. NASA had a pretty stiff requirement for performance with regard to those two parameters. We thought that it could be done optically. The real question was, could it be done in a form that was practical to put on a person's head? And that was the real challenge — achieving the performance in a package that was usable," said Christopher Lewis, president of n-Vision.

The core design elements of the Datavisor 80 are the two optics legs, each of which contains a miniaturized CRT, liquid crystal color shutters, and a prism bent at right angles to an array of lenses and a mirror. The tolerances required to corral light from the CRTs are precise and involve the exacting placement of 11 lenses in a single assembly.

Once the company developed the optical and display systems that met NASA's stringent requirements for high resolution, wide field of view, and minimum eyestrain, the question shifted to how the two optics legs — relatively heavy assemblies of metal, plastic, and glass — could be mounted in a headset that weighed less than five pounds and was comfortable to wear.

Industrial designers at ION Design of Edgewater, NJ, collaborated with n-Vision to design an exoskeleton with the optics attached. The resulting Datavisor 80 looks like a crown with eyepieces. The CRT housings ride horizontally above either side of the head, and the right and left side lens barrels extend down to eye level. ION used an IGES file of a human head to try out positions for the optics legs, and they modeled some human eyeballs in Pro/ENGINEER® automated product development software from Parametric Technology Corp. of Waltham, MA, in order to align the exit pupils of the optics assembly.

The prototype of the system to be presented to NASA contained about 70 different parts from 19 vendors. "All of these parts had to fit together," said Minoo Bablani, n-Vision's product development engineer. "The first prototype we made took us three or four days to build, once we had all the parts. It fit very well, and all the people were very excited, especially with the field of view and the resolution. With Pro/ENGINEER, we could visualize how the headset was going to look and fit, but nobody could model the experience of what we were going to see when we put the 80 on our own heads. That visual experience of high resolution and wide field of view validated the product concept, the teamwork, and the power of our CAD system to accurately model all the components in the HMD."

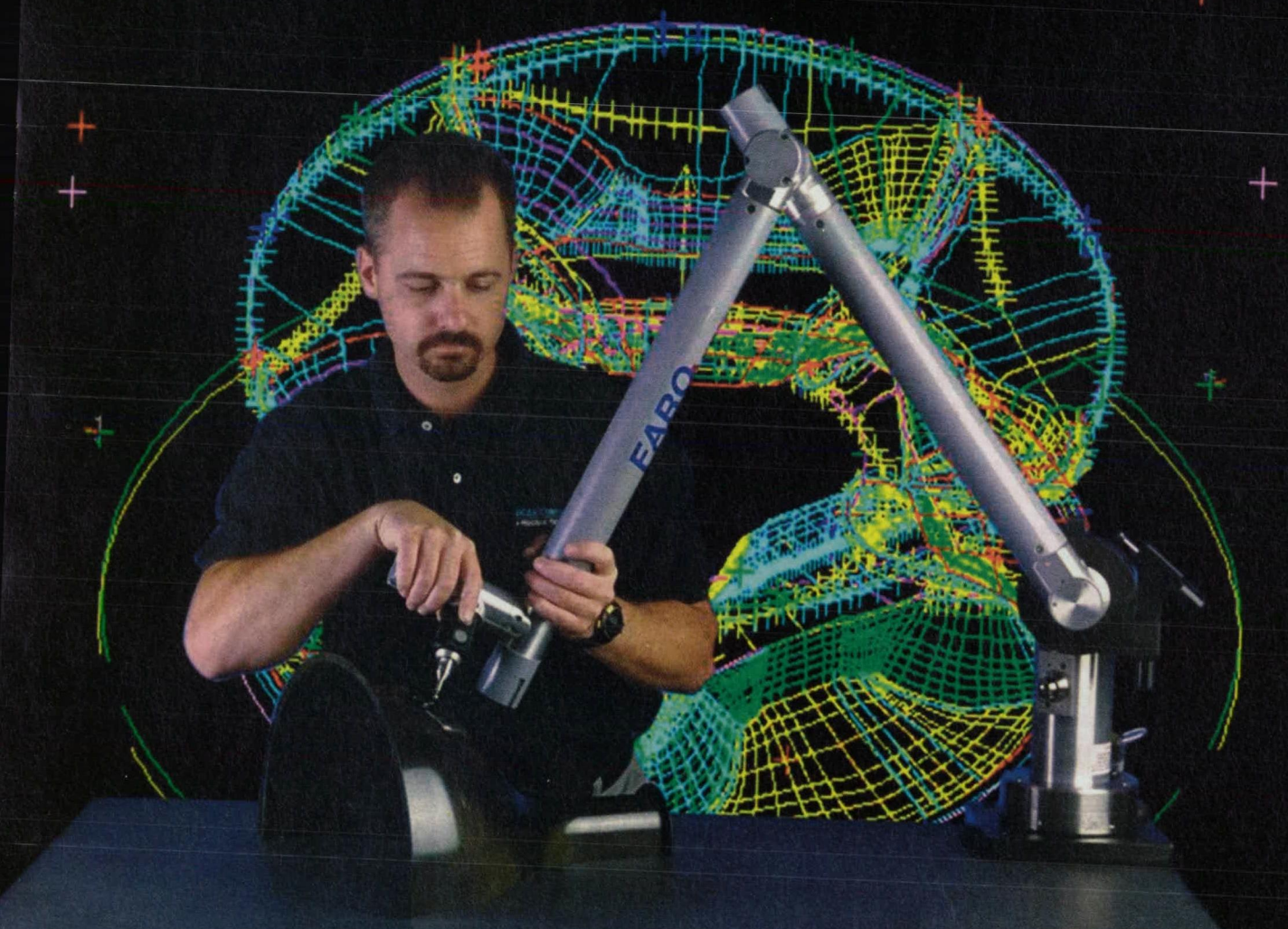
NASA continues to use n-Vision HMD systems, and used the company's Virtual Binoculars for the Mars Pathfinder mission to view the landscape of Mars from stereo cameras attached to the Sojourner rover.

For More Information Circle No. 756

Rapid Product Development

Latest RPD Tools On Display in Boston

New Products – page 14b



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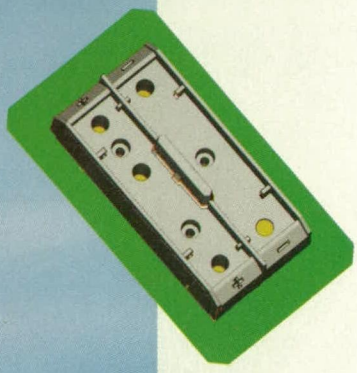
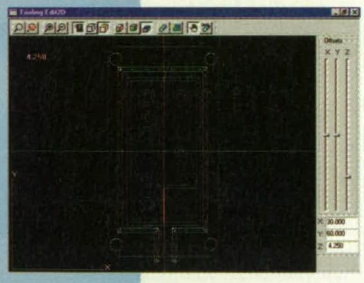
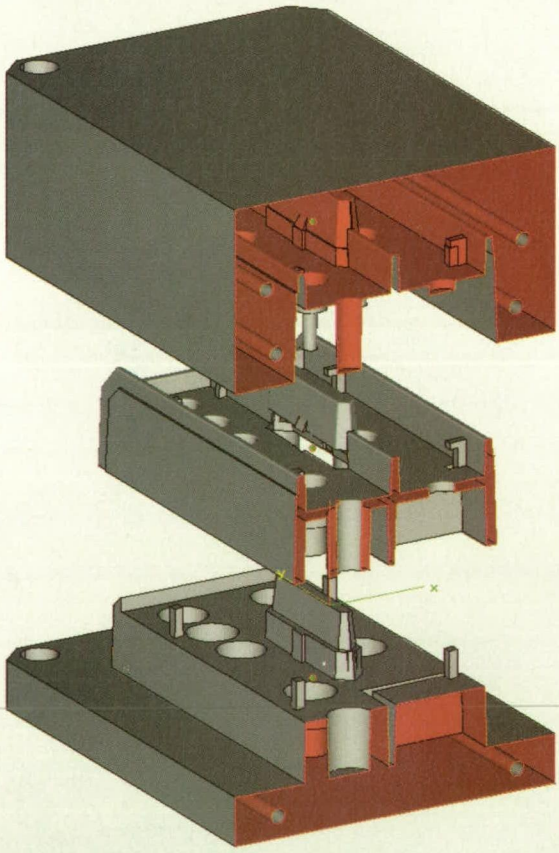


Parting Plane Definition

Rapid Tooling is FAST Tooling



Parametric Editing of Cooling and Gating



Core & Cavity creation with Cooling channel in Mold Preview (cut away view)

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Welcome to *RAPID PRODUCT DEVELOPMENT.*

This new bimonthly supplement to *NASA Tech Briefs* is designed specifically for you — the OEM engineer/manager involved in CAD/CAM who is looking for new tools to produce better products faster. It's no secret within the engineering community that the product development cycle and time to market are being compressed dramatically as manufacturers face increasing global pressure. How do you find the right time-saving tools to meet these demands without sacrificing quality or breaking the bank? That's where *Rapid Product Development* — the only U.S. publication dedicated to the rapidly-evolving RPD market — will help.

Our editors will be reporting on the latest technologies and products in computer-aided design, engineering, and manufacturing; finite element analysis; modeling; reverse engineering; rapid prototyping; and rapid tooling. You'll find application stories, news and market trends, tech briefs, tutorials, product announcements, and supplier guides… to aid you in making informed decisions about which RPD tools match your company's needs.

In this issue, for example, we describe how Boeing engineers utilized simulation software and laser projection technology to cut in half the time required to manufacture a new composite aircraft wing (page 2b); how virtual modeling enabled the Lear Corporation's Advanced Math Modeling Group to save money and labor by eliminating the traditional prototyping process of building clay models (page 5b); and how NASA and Auburn University have teamed to create the first accurate computer models of molten metals and molding materials used in forming cast metal parts, accelerating the development cycle for rocket turbines and many other types of machinery (page 6b).

We also have a preview of the Rapid Prototyping and CAD Pavilion in the New England Design & Manufacturing Expo (November 3-5, Boston's Hynes Center). If you would like more information from any of the exhibitors profiled, circle the corresponding number on the fax-back form (page 33).

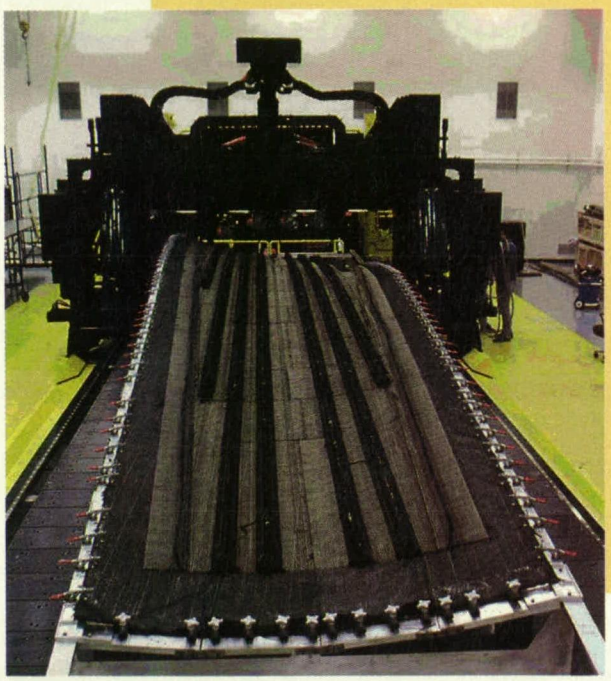
Please let me know what you think of this new publication. Send your comments and suggestions to joe@abptuf.org. If you would like to share stories about how RPD technologies have saved your company time or money, please contact our Chief Editor, Linda Bell, at linda@abptuf.org, or call 212-490-3999, ext. 255. Look for the next edition of *RPD* inside the January issue of *NASA Tech Briefs*.

Joe Pramberger
Publisher

ON THE COVER:
This 3D CAD image of a Navy LSD-49 Wildcat winch was reverse-engineered by HighRES Inc., La Jolla, CA, using their proprietary software and a FARO digitizing arm. Image courtesy of HighRES Inc. (www.reverse-it.com) and FARO Technologies (www.faro.com).

CAD software and laser projection bring textile-industry technology to Boeing's aircraft manufacturing process.

SHORTENING THE SPAN IN WING DESIGN



Semi-span wing status. Lower cover panel with stringer attached.

Computer software that makes a direct link from three-dimensional CAD geometry to automated ply cutters and laser projection systems provided about a 50-percent time savings in the manufacture of a new composite wing design at the Boeing Company, Huntington Beach, CA. FiberSIM simulation software from Composite Design Technologies of Waltham, MA, allowed designers to define composite layup on the computer, eliminating the need for trial and error on the shop floor that normally takes up the bulk of development-cycle time. The software was part of a new composite manufacturing process based on stitched resin film infusion (RFI) that prevents delamination, allowing fabrication of full-span composite wings. Stitched RFI technology is expected to reduce wing weight by 25 percent and cost by 20 percent within 3 years.

Laminated composites have emerged in recent years as a high-performance, low-weight, cost-effective replacement for metal in many aerospace applications. Yet up to now the commercial aircraft industry has made only minimal use of them to manufacture wing and aircraft structures. The primary concern has been the risk of damage from delamination caused by manufacturing-induced defects or by impact with runway debris, hailstones, or birds. Another concern is the difficulty in manufacturing the very large composite structures required for aircraft wings at a cost competitive with state-of-the-art aluminum wings.

In the 1980s, researchers began investigating new manufacturing techniques, including knitting, weaving, and braiding, modeled after existing textile manufacturing technology. Stitching combined with RFI showed the greatest potential for overcoming cost and damage-tolerance barriers to wing structures. Assembling carbon fabric preforms with closely spaced through-the-thickness stitching provided essential reinforcement to prevent delamination. Also, stitching made it possible to incorporate the various elements—wing skin, stiffeners, ribs, and spars—into an integral structure that can eliminate thousands of metal fasteners.

An Advanced Stitching Machine

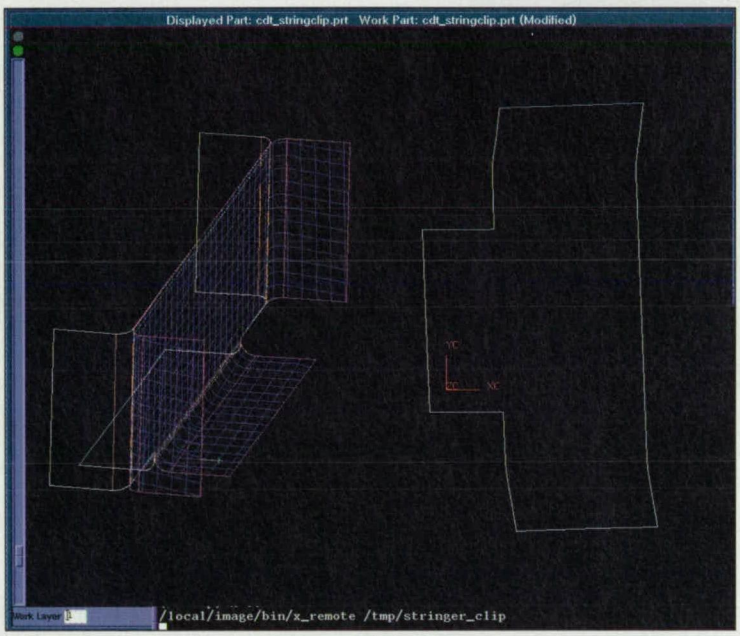
NASA awarded Boeing the contract to develop a machine capable of stitching contoured aircraft-wing surfaces at a very high speed. Ingersoll Milling Machine Co. of Rockford, IL, was selected to design and build the advanced stitching machine (ASM), which is capable of stitching one-piece wing-cover panels 40 feet long and 8 feet wide at a rate of 3200 stitches per minute. The ASM combines high-speed stitching with advanced automation, allowing it to stitch large, thick, complex wing structures with minimal manual intervention.

As this machine was being developed, refinements were also made to the entire composite fabrication process. The traditional manual approach involves cutting raw fabric into plies using hand templates. The initial plies would be located and aligned on the stitching machine surface with the assistance of scribe lines, templates, and measurements. But many of the plies for a commercial aircraft are 40 feet or longer, making them cumbersome to handle using the conventional approach. So engineers developed an alternative that uses the latest CAD/CAM technology based on FiberSIM software, as well as automated material cutting and laser projection techniques.

The new process begins with the definition of the part geometry, including the mold surface, ply boundaries, holes, splices, and helpful markers using the Unigraphics CAD/CAM system from EDS Unigraphics, Maryland Heights, MO. Boeing engineers then use simulation with FiberSIM to test the producibility of ply shapes and orientations. The software is completely integrated with Unigraphics (as well as with CATIA and Pro/ENGINEER) so that its commands appear within standard CAD menus. Engineers run the FiberSIM flat-pattern function to generate net flat patterns for the complexly curved multisurface plies that take the thickness of laminate components into account. The software automatically models the deformation mechanism that woven and unidirectional materials undergo during lay-up, changing their surface area. This process provides significant time savings and also greatly reduces the need for manual trimming of the resulting patterns.

Once they have created satisfactory flat patterns, Boeing engineers use FiberSIM to export the CAD data to a numerically controlled ply cutter from GGT Cutting Edge, Marblehead, MA. A commercial supplier delivers multiaxial warp-knit fabrics stacked as specified by Boeing, and then the stacks are cut by the automated cutter into the preforms that generate the shape of the wing. Since FiberSIM produces net flat patterns with limited excess and the ply-cutting nesting software optimizes the position of the plies on the bed, material waste is reduced by 25 percent compared to the older process. Automated cutting also provides a cleaner cut and more precise ply shape while eliminating the need to make the templates required when cutting by hand, resulting in additional cost savings.

The next step is to lay up the cut plies on the stitching machine bed using a laser projection system (LPS).



FiberSIM-generated fiber orientations and net flat pattern for the composite wing stringer clip.

Since the FiberSIM software creates both the shapes to be cut and the ply boundaries projected by the LPS, two-dimensional patterns can be cut with the assurance of three-dimensional tool conformity. Consequently, Boeing engineers used FiberSIM software to produce three-dimensional ply boundary, hole, splice, and marker data for the LPS, made by General Scanning, Watertown, MA. Data generated by FiberSIM was read by the LPS, and the laser heads projected ply data on the stitching machine bed in the exact location where the material should be placed. Lay-up technicians then placed the precut plies between the continuous laser lines in a predetermined, preprogrammed sequence. When generating laser projection data, FiberSIM automatically accounted for material thickness and offset due to ply buildup. This eliminated parallax errors due to accumulation of ply offset from the tool surface that could arise when manually programming the LPS. Preprogramming the lay-up sequence with FiberSIM cut lay-up time by about half. An additional benefit was the ability to use the laser projection system to check the lay-up for accuracy.

A Matter of Control

Since FiberSIM generated data for both the LPS and the cutting system directly from the CAD model, engineers were able to close the loop between the lay-up station and the 3D CAD model. Any discrepancies between the CAD model and manufacturing data were easily detected, since net plies were expected to fit precisely within the projected laser lines. This gave the engineering staff complete control over ply layouts. Furthermore, the direct link that FiberSIM provided from the CAD model to the manufacturing equipment drastically reduced the amount of time required on the shop floor to prepare plies for cutting and also insured that manufacturing would build exactly what the designer had designed into the 3D CAD model. The accuracy and seamless nature of this link was assured by the fact that Composite Design Technologies maintained close contact with equipment manufacturers to insure that FiberSIM output was compatible with composite manufacturing equipment.

Once the fabric pieces were arranged in the proper position, the ASM stitched the stacks to make a solid wing preform. The stiffeners and rib clips for wing covers were made using a braiding process that made it easier for them to conform to the contours of the wing. Braided tubes were collapsed and stitched to make blade-shape stiffeners and rib clips. In a final step, the ASM stitched the stiffening elements to the skin preform. The result was an integral wing-cover preform, ready for the RFI process.

Continued

The still-flexible wing-skin panel was put into an outer mold line tool that was the shape of the outside surface of the wing. A film of resin was laid on the form, followed by the stitched skin preform and the tools that would define the inner mold line. These elements were put into a plastic bag from which the air was drawn out to create a vacuum. The materials were then placed in an autoclave, where heat and pressure were applied to let the resin spread throughout the carbon fiber material. After heating to 175 °C for two hours, the wing-skin panel took on its final hardened shape.

Time and Cost Savings

The new RFI process eliminates the cost of conventional prepregging and its time-consuming setup. Stitching materials requires less manual labor than drilling holes and assembling the 80,000 metal fasteners used in an aluminum wing. Wing cover panels can be stitched in one two-shift operation, compared to the several days required for conventional composite fabrication processes. Removal of this excess metal also decreases the weight of the wing and eliminates the problems of fatigue and corrosion of metal fasteners. Panels now being stitched will be used as test articles in full-scale ground testing next year to assure that the stitched structure meets Federal Aviation Administration standards. Ultimately, engineers expect this new technology will find wide usage early in the next decade, helping to meet NASA's goal of reducing the costs of air travel by 25 percent within ten years.

This application provides a dramatic example of how CAD/CAM technology can help to develop innovative new composite manufacturing processes at a competitive cost and a reasonable cycle time. By using software tools such as FiberSIM that close the loop between design and manufacturing, Boeing was able to nearly eliminate trial and error on the shop floor while insuring that the finished product perfectly matched the design intent. Boeing is using FiberSIM technology to create nose fairing for the Delta III rocket and in other programs such as the F-22, V-22, F-18, Apache helicopter, and the 737, 767, and 777 aircraft.

This article was prepared by Mike Karal, deputy project engineer, and Patrick Thrash, technical specialist, at the Boeing Company, Huntington Beach, CA. For more information, contact Composite Design Technologies Inc., 235 Wyman St., Suite 110, Waltham, MA 02154; (781) 290-0506, ext. 223; fax: (781) 290-0507; www.cdt.com.

"Virtual Modeling" Cuts Product-Development Time

Inside view of interior seat side shield surface modeled in ICEM Surf.

Interior seat side shield surface modeled in ICEM Surf; finished, or outside, view.

The Lear Corporation, based in Detroit, is among the world's leading suppliers of automotive interior systems. The company's Advanced Math Modeling Group has solved many thorny design problems for major auto manufacturers, including Chrysler, Ford, Mazda, and Toyota. Design challenges have ranged from troubleshooting a faulty visor clip, to a complete revamping of a minivan interior.

Not long ago, a Japanese automaker asked the Advanced Modeling Group to complete an ashtray assembly design — in three weeks. Using a conventional NURBS-based system, this project would normally take up to six weeks because of the differences in surface development. This time, instead of a traditional CAD system, the Advanced Modeling Group used a Class A surface modeling product called ICEM Surf from ICEM Technologies of Arden Hills, MN.

"We not only met the deadline, we gave the customer a fully surfaced CAD model — Class A and back side," said Rich Blue, manager of Lear's Design Business Unit. The automaker was then able to generate a functional stereo lithography model prior to tooling the component.

"We were used to the standard, conventional CAD modeling systems where you build curves first and then build surfaces around those curves," said Matt Pyzik, head of Lear's CAD modeling team. "With ICEM Surf, you create surfaces first. When I have a complex surface with a conventional CAD system, the opportunity for surface imperfections is much greater."

ICEM Technologies is a division of Parametric Technology Corporation, and was formed in 1995 to develop advanced software solutions for computer-aided product design and manufacturing. ICEM Surf allows what the company calls "global modeling" by enabling users to modify many surfaces together, working both the Class A (finished side) and Class B (back side) surfaces of the material.

According to the company, ICEM Surf allows surfaces to be generated, diagnosed, visualized, and modeled dynamically in real time. All work can be performed directly on an accurate 3D surface model that can be rotated and positioned. Stylists can use this model as if it were made of virtual clay; surfaces can be manipulated and stretched in real time. As changes are made, the highlight reflections, section curves, shaded displays, and surface textures are dynamically updated. What the designer sees onscreen is exactly what will be produced during machining.

Changing the Rules

The traditional design process typically has included building a clay model, scanning it, surfacing the scan data, creating a proveout model of the surface, review and surface modifications, proveout model changes, and the cutting of a tool. Recently, when Lear's team received engineering data outlining all sections needed for certain interior components, the stylist used the information to generate a "treasure map," calling out fillets, radii, and a general shape. By using ICEM Surf to design Class A and B surfaces, Lear was able to eliminate the clay model for one component and the proveout model for another.

In a job for a minivan producer, the Advanced Math Modeling Group was asked to make extensive changes in an interior to accommodate a new AC system, packaging of a different window mechanism, and a new automatic sliding door. From rough scan data supplied by the client, Lear was able to create a millable surface for the entire interior within a few weeks.

Lear also has used ICEM Surf for troubleshooting designs, such as a visor clip that malfunctioned on a particular truck model. The Advanced Math Modeling Group compared laser scan data from the tool with the original CAD data, recreated both sides of the part in ICEM Surf, and collaborated with the engineering team to make the part fit correctly.

"The ultimate goal of all automakers is to eliminate the expensive and time-consuming process of prototyping," said Blue. "Lear already has shown how we can help them do that. In fact, the combination of our top-quality staff and our ICEM Surf design system makes us one of the best resources for design services."

For more information, contact ICEM Technologies, 4201 Lexington Ave. North, Arden Hills, MN 55126-6198; Tel: 800-799-3932; www.icem.com

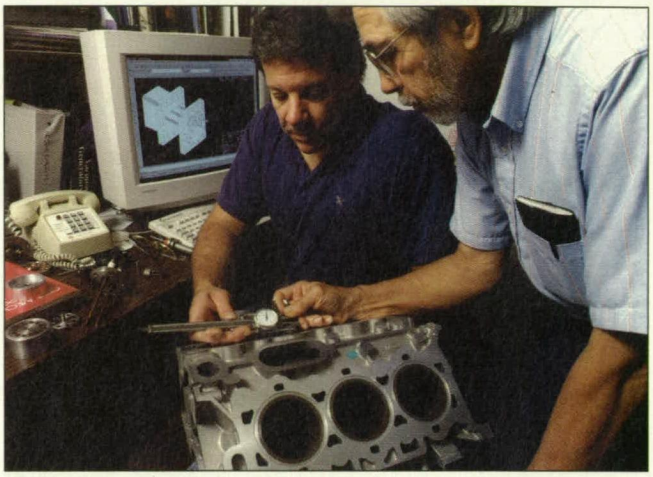
Low-Gravity Research Helps Improve Cast-Metal Products

Research in low gravity has taken an important first step toward making metal products used in homes, automobiles, and aircraft less expensive, safer, and more durable. NASA is collaborating with Auburn University in Auburn, AL, and with private industry to develop the first accurate computer model predictions of molten metals and molding materials used in forming cast-metal parts. The computer information is based on research conducted on the ground and in low-gravity conditions aboard a NASA KC-135 aircraft.

Howmet Industries of Whitehall, MI, is using the new computer technology to more precisely design and cast aircraft turbine blades. In a similar project, Ford Motor Company's Casting Plant in Cleveland, OH, is using information from the new computer models to improve the casting process of automobile and light-truck engine blocks.

Cast-metal parts are used in 90 percent of all durable goods such as household appliances, lawn mowers, cars, boats, and aircraft. According to the American Foundrymen's Society in Des Plaines, IL, sales of cast parts in the U.S. alone total $25-30 billion a year. "Partnering with NASA offers unique research opportunities to improve methods of production used in the foundry industry to enhance the quality of castings," said the Society's director of research, Dr. Joe Santner.

High-temperature metal-alloy parts for the aerospace and auto industries can strengthen aircraft and vehicles, while making them lighter and more efficient. But developing an effective casting process usually takes three or four years.



Ford Motor's Casting Plant is using NASA-sponsored computer modeling to improve the casting process for engine blocks. Bruce Strom (left) of Auburn University evaluates an aluminum engine block casting with Don Sirois, an Auburn research associate.

"We started with experiments on the ground," said Dr. Tony Overfelt, director of Auburn's Solidification Design Center. "Then we went aboard a NASA KC-135 aircraft flying an arc pattern in low gravity to refine our research. Our goal is to continue to produce accurate measurements for all the alloys used by the casting industry. This information can be used by American manufacturers to standardize metal-mixing 'recipes' and to compete more effectively in the worldwide market."

Dr. Thomas Tom, director of advanced technology for the Howmet Corporation, said that the research already has benefited his company. "The NASA and Auburn University-led research project on turbine-blade castings helped us realize a cost savings and accelerated the development cycle for rocket hardware."

Other participants in the casting-research project include Anter Corporation, Pittsburgh, PA; Thermophysical Properties Research Laboratory, West Lafayette, IN; PCC Airfoils, Beachwood, OH; and the American Foundrymen's Society.

Auburn University is one of NASA's 10 Commercial Space Centers. These centers serve as a focal point for NASA partnerships with industry and universities, encouraging space-related research opportunities to develop new products and services. NASA's Commercial Space Center program is managed by the Space Product Development Office of the Microgravity Research Program at the Marshall Space Flight Center in Huntsville, AL.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TECH EAST '98

New England Design & Manufacturing Expo

New England Design & Manufacturing Expo:

Focus on Rapid Product Development

Tech East '98 is an alliance of six major technology events in one place, at one time. Held from November 3-5 at Boston's Hynes Convention Center, Tech East '98 includes Technology 2008 (The Engineering Innovation Show) and the first annual New England Design & Manufacturing Expo, sponsored by *NASA Tech Briefs* magazine. Central to this event is the Rapid Prototyping & CAD Pavilion, where exhibitors will demonstrate hardware and software tools that enable engineers to compress the product-development cycle and speed time to market. The following industry leaders will be displaying their cutting-edge products.

• Advanced Microelectronics
(Booth 2811)

Based in Nashua, NH, Advanced Microelectronics specializes in electronic circuit/packaging design and manufacturing services, including prototypes, SMT, COB, MCM, hybrids, test probes, and miniature products.

Circle No. 782

• Agile Software Corporation
(Booth 2806)

Agile Software of San Jose, CA, provides Windows and Java client/server applications for desktop-based product data management (PDM), engineering change control, and supply-chain management, with out-of-the-box interfaces to leading ERP systems.

Circle No. 783

• Armstrong Mold
(Booth 2802)

Armstrong Mold, East Syracuse, NY, provides leading manufacturers with a comprehensive range of prototyping and short-run production services, including high-precision cast tooling for injection molding.

Circle No. 784

• ARRK Product Development Group
(Booth 2817)

This San Diego-based company's capabilities include rapid prototyping, CAD/CAM machining, fabrication, vacupressure molding, rapid castings, pre-production injection molding, and complete model-making services.

Circle No. 785

• C2C Technologies
(Booth 2812)

C2C Technologies is a new product-development services company that assists I-DEAS users in improving time-to-market by providing access to rapid prototyping, rapid mold making, and rapid part production. C2C is based in Millburn, NJ.

Circle No. 786

• Coherent
(Booth 2815)

Located in Santa Clara, CA, Coherent designs and manufactures lasers, laser diodes, and laser systems for imaging, holography, inspection, material processing, metrology, data storage, and printing markets.

Circle No. 787

• Haptic Technologies
(Booth 2814)

Haptic Technologies of Montreal, Canada, develops and markets "haptic" products — computer peripherals and software technologies that stimulate the sense of touch via high-fidelity force feedback.

Circle No. 788

• Marchetti Design & Engineering/Baystate
(Booth 2820)

Marchetti, based in Leominster, MA, is a leading reseller in the CAD industry, as well as an Authorized Training Center. In April, Baystate Technologies named Marchetti the Number One 1998 CADKEY Regional Dealer.

Circle No. 789

• Romer
(Booth 3216)

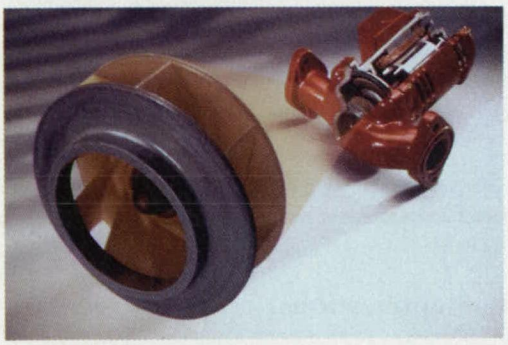
Romer manufactures and distributes the Romer portable CMM. This six-axis articulated-arm CMM reaches anywhere you can and provides accurate measurements down to 0.001". The system's powerful and intuitive software guides the operator to put measurements to maximum use. Romer is located in Enfield, CT.

Circle No. 790

• Sanders Design International
(Booth 2808)

Located in Wilton, NH, Sanders offers the Sanders Model-Maker™ System, which produces precision prototypes rapidly and accurately for direct casting of parts.

Circle No. 791



• Spacetec IMC Corp.
(Booth 2810)

Spacetec IMC of Lowell, MA, offers the Spaceball FLX 3D Motion Controllers, which allow users to pan, zoom, and rotate 3D models with six simultaneous degrees of freedom control.

Circle No. 792

• Stratasys
(Booth 2807)

Based in Eden Prairie, MN, Stratasys offers the easy-to-use Genisys 3D printer, which produces fast iterations of concepts early in the design cycle. It generates 3D prints in durable polyester compound.

Circle No. 793

• Unigraphics Solutions
(Booth 3026)

Unigraphics will demonstrate Solid Edge, a parametric feature-based solid modeling product, and Unigraphics products, offering a complete mechanical CAD product line.

Circle No. 795

• Z Corporation
(Booth 2809)

The company manufactures the Z402™ 3D printer, an affordable rapid-prototyping system for use in an office environment. It builds parts of virtually unlimited geometric complexity, directly from CAD files. Z Corp. is located in Somerville, MA.

Circle No. 794

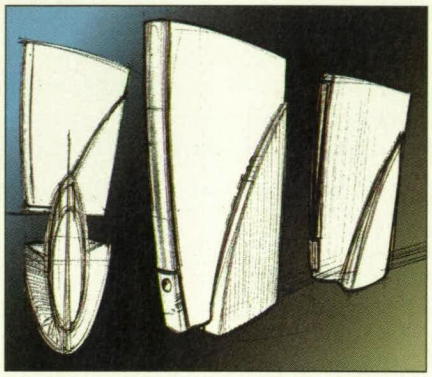
To obtain more information on any of the exhibitors described here, circle the corresponding number on the Fast Fax Information Form on page 33, or visit the *NASA Tech Briefs* web site at: **www.nasatech.com**. For more information on Tech East, visit **www.techeast.net.**

Innovative Design Techniques Slash Time to Market

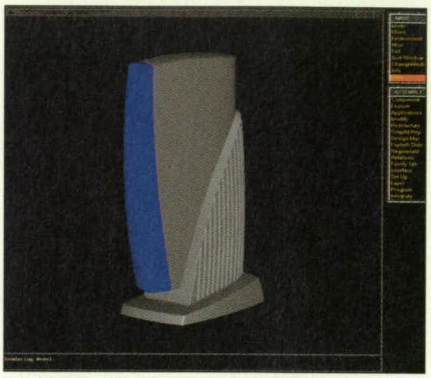
Upending convention, Compression Inc. uses concurrent engineering to get a modem into distribution in record time.

Compression Inc., Louisville, Kentucky

When Viking Components Corp., a well known manufacturer of computer memory and internal modems, made a strategic decision to enter the marketplace for 56-K external modems, it looked around for a design vendor who could meet the demands of a very stringent development schedule. Viking chose Compression Inc., whose corporate headquarters are in Louisville, KY. Compression calls its techniques vertical integration. Its slogan is that vertical integration creates accountability, which the company achieves through aggressive program management.



Viking's new 56-K modem took form through conceptual design studies in Compression's industrial design department.

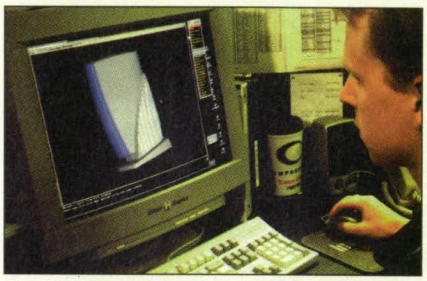


Working with the industrial designers, Compression's mechanical engineers translated the design into a 3D CAD model.

To meet Viking's demands and its tight introduction date, Compression's team rethought the size, shape, and functionality of the new modem. For one thing, the PC board to be used was uncharacteristically large, in part because Viking wanted one design that could be adapted to future, more powerful products to avoid redesign costs and time. Compression's designers came up with an innovative idea, a vertical configuration that accommodates the larger board but retains a competitively small footprint of 2 ½ × 4 ½ inches.

John Goodin, Compression's program director on the Viking project, notes that "when you are dealing with a commodity item, quality of design is a factor that is equal in importance to ease of servicing and manufacturability." In the case of the modem, Viking's engineering and marketing managers had no hesitation in approving it.

Goodin calls the design, modeling, tooling, and production process a case of true concurrent engineering: the goals of design and the requirements of the electronics capabilities were pursued in parallel. Compression's mechanical engineering department translated the 2D conceptual drawings produced by the industrial design department into 3D CAD files. These were then used by the rapid prototype department to create a painted stereolithographic appearance model, which served a number of functions. It was used by the electronics designers to prove out the compatibility of the case, its internal components, and such factors as the location of connectors and mounting holes. Second, it served to validate the manufacturability of the product as designed. Finally, it provided Viking with a preproduction prototype that could serve advertising, packaging, and sales promotion ends.



The CAD database was also used for tool design.

The final time-critical step was tool design. Compression's tool design and CAM department created mold splitting and tooling files, and tooling began. Four weeks later the company "shot" the first article parts for mold evaluation and delivered them to Viking for approval, after which an initial production run of 17,000 units began.

As Goodin put it, "In 12 weeks the modem was on the shelf selling through distributors." A conventional process of linear decision-making rather than concurrent engineering could have consumed as much as eight months, he estimated.

For more information on the Viking Corp.'s modem, consult the web at http://www.vikingmem.com/. For more information on **Compression Inc.** *and its services, call 1-888-SPD-2-MKT (1-888-773-2658).*

Laser Engineered Net Shaping (LENS™)

Rapid tooling and tool repair are the developmental target applications.

Optomec Design Co., Albuquerque, New Mexico

The Laser Engineered Net Shaping (LENS™) process builds metal parts with excellent material properties directly from computer-generated models. The process was initially developed at Sandia National Laboratories (SNL) by David M. Keicher and his team. SNL continues to make advances in the process through internally funded efforts as well as a Cooperative Research and Development Agreement (CRADA) with industry. In parallel, Optomec Design Co. is developing the technology for commercial markets under a license with SNL.

The LENS™ process is functionally similar to many of the existing rapid prototyping methods in that it builds an object a layer at a time. A computer-generated solid model is sliced electronically into a series of layers, in .STL file format, that are subsequently used to control the deposition of successive layers of material, thus building the part a layer at a time. A schematic representation of the process is shown in Figure 1.

To begin the fabrication process, a metal substrate is used as a base onto

which new material is deposited. A high-power laser is focused onto the substrate to create a molten puddle, and metal powder is injected into the puddle. The substrate is moved relative to the laser beam, under computer control, to deposit thin metallic lines of a finite width and height. These lines are deposited side by side in the desired regions to create the pattern for each layer. In this fashion, each layer is built up line by line while the entire object evolves, layer by layer.

The process is limited in the amount of overhang that can be achieved to a maximum of 30 degrees. This limitation does not adversely affect its effectiveness for rapid tooling applications. Therefore Optomec chose rapid tooling and tool repair as the initial target application. The current interest in this application is high, as evidenced by the number of conventional rapid prototyping processes that are being used, with subsequent processing, to produce "rapid" tools.

Optomec's technical development began in January of last year when Keicher joined Optomec as a full-time employee. The effort has been funded primarily through three Small Business Innovation Research (SBIR) projects, from the National Science Foundation (NSF), the Ballistic Missile Defense Organization (BMDO), and the Department of Energy (DOE).

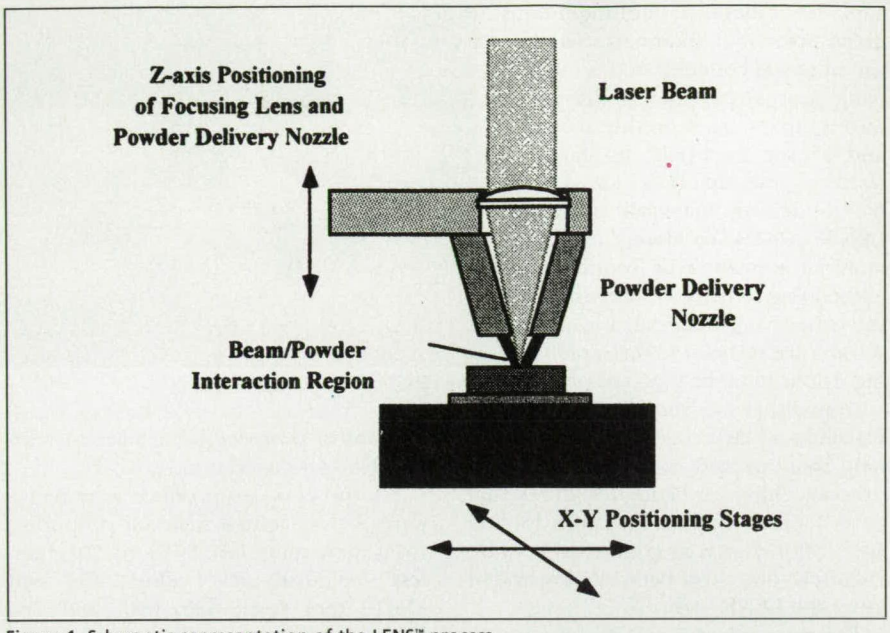
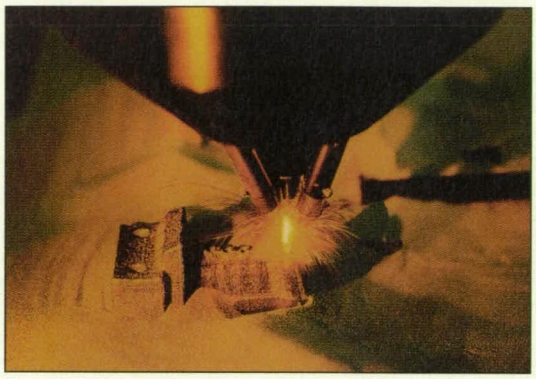


Figure 1. Schematic representation of the LENS™ process.

The purpose of the NSF project was to demonstrate the feasibility of using the LENS™ process to produce molds for injection-mold tooling applications. A simple mold was produced using the process and a quantity of parts was produced from the mold. Its feasibility for producing molds for plastic parts was demonstrated, and also the ability to incorporate the starting substrate into the final tool.

The purpose of the BMDO project was to demonstrate the feasibility of using the process to fabricate embedded sen-

sors in otherwise homogeneous metal structural materials. To date the work has concentrated on identifying process parameters that minimized mixing between the structural and sensor materials. So far, this work suggests that it is indeed feasible to deposit materials using the LENS™ process to create an abrupt material transition as required for embedding sensors without affecting the underlying material. Embedded sensors are relevant to the rapid tooling application in that temperature and pressure sensors, strategically placed in a plastic injection mold, could help monitor and control the molding process. Other embedded features that have a direct impact on rapid tooling applications, such as conformal cooling channels, have also been demonstrated using the LENS™ process.



The LENS™ process in action.

The purpose of the DOE project was to study novel methods to improve surface finish and tolerances on parts produced with the process. Statistically designed experiments were conducted using an Optomec proprietary laser remelt process. These resulted in a unique process that showed surface finish improvements, from about 400 microinches, which is achieved with the LENS™ process, to about 10 microinches. Thus the basic LENS™ process is capable of producing near-net-shape tooling, and the possibility of improving surface finish promises to minimize the amount of postprocessing necessary on a LENS™-produced tool.

The process can produce fully dense parts with excellent material properties from these materials: 304 and 316 stainless steel; iron-nickel alloys; H13 and MM10 tool steel; 625, 690, and 780 Inconel; titanium alloys; tungsten; and Haynes 230. Build rate is 0.2-0.6 in.3/hour, laser power ranges from 150-700 W, and powder usage efficiency is 10-30 percent.

Advancing the technology to the point where industrial-grade systems can be produced requires a great deal of additional research and development in an industrial environment. Optomec sees the need for research-grade LENS™ systems that will allow researchers to develop their own proprietary recipes and investigate proprietary applications that will ultimately define the characteristics and specifications of commercial industrial systems.

Optomec has consequently embarked on a technology commercialization effort to produce research-grade systems in alpha, beta, and finally commercial versions. Two alpha systems already produced function essentially like experimental systems in use at SNL, but with "product" embodiments such as packaging, ergonomics, and Windows-based software. One of the alpha systems was built under contract to Ohio State University, where it will be used for materials research, and the other alpha system will remain at Optomec. The next phase of Optomec's commercialization plan is to produce a limited quantity of "research beta" systems that will represent an incremental improvement beyond the alpha system and be representative of an eventual commercial research system.

For more information, contact Thomas A. Swann at **Optomec Design Co.**, *Albuquerque, New Mexico, who coauthored this article with D. M. Keicher and W. D. Miller; (505) 761-8250; www.optomec.com. The work described here was performed at Optomec supported under the following grant and contract numbers: National Science Foundation, grant no. DMI9661204; Ballistic Missile Defense Organization, contract no. DASG60-97-M-0107; Department of Energy, grant no. DE-FG03-97ER82448/A000; Ohio State University, contract no. RF758409.*

Reverse Engineering: From CT to CAD

Reverse engineering adds a new level of technological sophistication to the rapid prototyping industry.

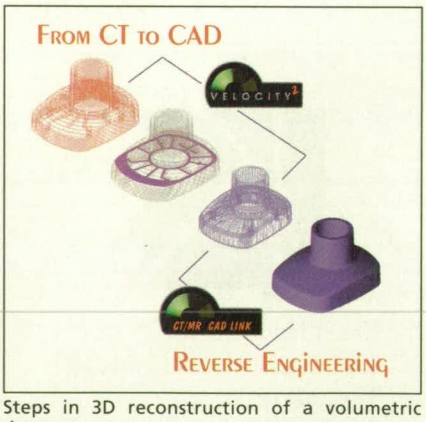
Image3 LLC, Salt Lake City, Utah

Many designers integrate 3D into their design process because they are looking for time-to-market improvements for better links to manufacturing. Unfortunately, 3D data is not always available for many commercially available products. Reverse engineering is the term used to describe the process of recapturing lost or damaged 3D design data for these products.

Most reverse engineering approaches involve imaging or digitizing an object and then creating a computerized reconstruction that can be integrated in 3D into the particular design environment. Relying on volume visualization technology, a fundamental technique for interpreting and interacting with large 3D data sets, it is possible to establish reverse engineering as an integrated step in rapid production and agile manufacturing.

Image3's innovative approach uses Velocity²™ and computed tomography (CT) data sets to reconstruct objects. Velocity², a modular software application for 3D reconstruction, rendering, and rapid prototyping, is Image3 LLC's showcase product. This package supports file output from volumetric image data sets as well as 2D-contour data sets that describe 3D objects. This proprietary software package, developed and owned by Image3, was specifically designed for medical and industrial markets with emphasis on rapid prototyping.

In CT imaging, a 3D image of an x-ray-absorbing object is reconstructed from a series of 2D cross-sectional images. An x-ray beam penetrates the object, and transmitted beam intensity is measured by an array of detectors. Each such "projection" is obtained at a slightly different angle as the scanner rotates about

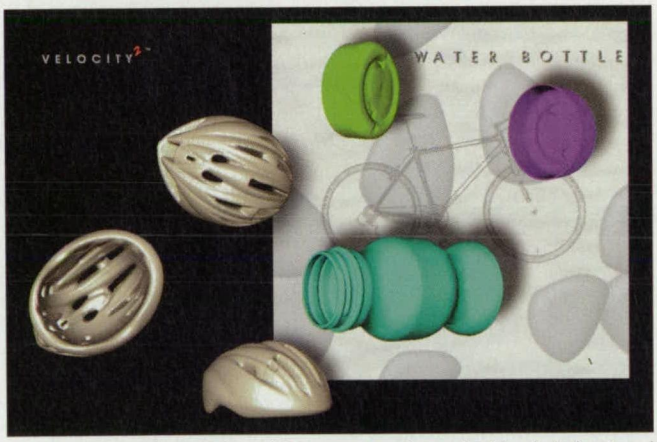


Steps in 3D reconstruction of a volumetric data set.

the object. The 2D image is computed from the projected images using the approximate method of "back projection" or the more accurate method of inverse Fourier transformation. CT was introduced in the early 1970s as a neurological examination technique, and later extended to industrial applications. It is a radiographic examination technique used whenever the primary goal is to locate and size planar and volumetric detail in three dimensions.

Current industrial CT systems can provide dimensional measurements at an accuracy competitive with coordinate measuring machines (CMMs). Of the existing methods for generating a CAD model of a physical part, only CT can nondestructively dimension internal as well as external surfaces. CT has the unique ability to detect and quantify defects. Additionally, it is indifferent to surface finish, composition, and material, and it can measure part coordinates as fast as laser scanner—and orders of magnitude faster than CMMs.

Because of the relatively good penetrability of x-rays, as well as the sensitivity of absorption cross sections to the density and atomic number of matter, CT permits the nondestructive evaluation (NDE) and, to a limited extent, chemical characterization of the internal structure of materials. Also, since the method is x-ray based, it applies equally well to metallic and nonmetallic specimens, solid and fibrous materials, and smooth and irregularly surfaced objects.



Graphic created from CT-based 3D reconstructions of a bicycle helmet and a mountain-bike water bottle.

3D reconstruction of a volumetric data set is accomplished by extracting a region of interest (ROI), closing the boundary or defining the edge(s), and reconstructing surface from ROI to ROI throughout the image set. The resulting 3D reconstruction consists of a highly accurate 3D surface comprised of triangles. Output to rapid prototyping devices is accomplished directly via a Velocity² module.

When working with scan data, it is fairly common to produce models that have large numbers of surface polygons. Very large files can be difficult to export to rapid prototyping systems. When this occurs, Velocity²'s polygon reduction program, PolyMerge, can be used to selectively reduce the numbers of surface polygons by collecting small triangles into larger ones in regions of the surface that are relatively flat. With PolyMerge, you specify this "surface flatness" as the deviation in the local surface normal vector, the "delta value," in units of angular degrees. For example, a perfectly flat surface, *i.e.*, one with a delta value of zero, will have no variation of the surface normal vectors from one triangle to the next; whereas, in regions of high surface curvature, the delta value will be large. Typically, delta values of 20-30 degrees provide reductions in numbers of triangles of 30 percent or more in flat areas of the model without significantly affecting surface detail.

In many cases the reconstruction may have surface irregularities simply due to noise in the original image set. In these cases, it is advantageous to smooth the surface prior to polygon reduction to remove local surface roughness. The smoothing algorithm used in Velocity²'s PolyMerge (and in Display as well) recalculates the locations of triangle vertices as the average of a given vertex and its immediate neighbors. Significant file-size reduction can be achieved, which greatly improves the ability to export reconstruction files in the rapid prototyping .STL file format to RP systems.

With good technique and data, CT scan accuracy generally falls within ±20 percent of the slice data. For a 1-mm slice this would equal ±0.2 mm. Slice or scan spacing is critical for 3D model reconstructions, and should not be confused with slice thickness. Anything over 3 mm is not acceptable for most complex structures. The accuracy in the Z axis is determined by the spacing.

ARACOR's CTM 500 industrial scan system reports an accuracy of ±0.001 in. with a resolution of ±0.007 in. and a tracking speed of 100-300 slices per hour. The ARACOR-built ICT-1500 CT system at Hill AFB, Utah, employs a 9-MeV linear accelerator and achieves a maximum resolution of 1 mm and a minimum scan time of 1 minute per slice.

For more information, contact Alair Griffin, CEO of **Image3 LLC**, *Salt Lake City, UT, and the author of this article; (801) 466-9176; fax (801) 466-5817; E-mail: javelin@lonepeak.com.* *The author acknowledges the following sources: Yancey, R. et al., "Integration of Reverse Engineering, Solidification Modeling, and Rapid Prototyping Technologies for the Production of Net Shape Investment Cast Tooling," (1996), Advanced Research and Applications Corporation (ARACOR), Dayton, OH; Haystead, J., "Computed-Tomography-Based Medical Imaging,"* Vision Systems, *Vol. 2, No. 7 (July 1997); Cyberform International, Inc., Richardson, TX, marketing literature (1996).*

NEW PRODUCTS

Digitizing System

Steinbichler Optical Technologies, Novi, MI, offers the Comet/OptoTrak automatic robotic digitizing system that combines a white light digitizing sensor with MotoMan's robot. Engineers can capture the 3D form of their designs on the shop floor, regardless of location. The system enables surface reconstruction, rapid prototyping, rendering and animation, large-format display visualization, and NC milling path output. It has unlimited measurement volume, and can be integrated into downstream processors. **Circle No. 776**

Rapid Prototyping Station

DTM Corp., Austin, TX, has released the Sinterstation 2500^{plus} system for rapid prototyping and manufacturing that utilizes SLS® selective laser sintering technology to create 3D objects by using a CO2 laser to fuse plastic, metal, and ceramic powders. Features include a new laser and scanning system, redesigned delivery system, and improved thermal control of the process chamber and laser module. The station's Sinterstation System Software is Windows NT-based; the system also comes with Materialise NV's Magics™ RP software that provides the ability to scale, rotate, offset, and slice STL files, as well as measure, edit, shell, and repair part files. **Circle No. 773**

3D Printer

The Genisys 3D printer system from Stratasys, Eden Prairie, MN, is a desktop unit that produces solid 3D parts in a matter of a few minutes to several hours. It is designed for quick reproductions of concepts early in the design stage. The system can be used to print 3D prints when the need for 3D output is urgent, or to model the first few iterations of a concept. The system also can print multiple variations of a concept or design to aid in deciding which version to pursue. The single-material system allows the user to print models directly from a workstation. AutoGen software orients and scales the part, slices the data, and automatically builds parts with a simple point-and-click command. The system operates on Windows NT, Sun Microsystem, Hewlett Packard, and Silicon Graphics workstations. **Circle No. 774**

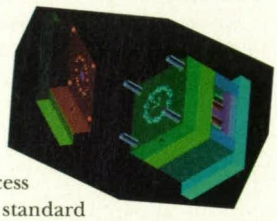
Reverse Engineering System

Romer, Carlsbad, CA, offers the Romer 1000 and 2000 series portable articulating arm coordinate measurement systems with a laser mini-cam probe that scans virtually all types of surfaces at a speed of about 7 lines per second. The probe, developed by Perceptron of Plymouth, MI, consists of a Class 2 laser, LED light array, and a sensing array. The probe attaches to the end of the Romer measuring arm, making it a portable data acquisition system that can be employed in the measurement and reverse engineering of a variety of products, including sheet metal panels, hydroformed components, plastic moldings, and other non-rigid 3D parts with complex contours. **Circle No. 780**

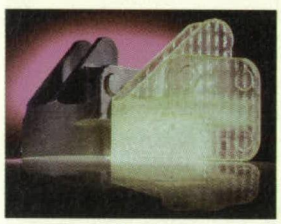
Optimization Software

NC Optimizer software from Sirius Systems, San Jose, CA, reduces manufacturing cycle times by up to 50% or more, according to the company, maximizing machine tool utilization and increasing manufacturing productivity. The software analyzes depth of cut, width of cut, and material removal volume in APT-CL and NC G code programs. It then adjusts the program feed and speed rates to reduce machining time. NC Optimizer accepts stock material, tool material and type, machining operation, and machine operating parameters as inputs to calculate and manipulate part program feed and speed values. **Circle No. 772**

Mold Design Software



Moldmaker Version 3.1 mold design software from Matra Datavision, Andover, MA, is based on solids design technology from EUCLID. It enables rapid creation of molds, cavities, and tooling for the plastic injection process using predefined components from standard libraries or in-house designs. It can be used for both small and complex molds, and runs on Windows NT and UNIX platforms. The software includes a series of standard mold bases and catalog components, which are selected interactively and imported into the working session. The program includes a solid modeler, and provides automatic creation of 2D drawings. **Circle No. 778**

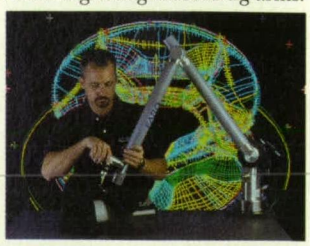


Resins for Prototyping Systems

SL 5220 and SL 5520 resins for use in rapid prototyping systems are available from 3D Systems, Valencia, CA. Cibatool SL 5520 resin, for use with the company's SLA-3500 and SLA-5000 rapid prototyping systems, was designed for snap-fit applications, providing form, fit, and functional testing of new products in development. The resin can make prototype parts and assemblies, and is low in viscosity. The SL 5220 resin, for use with the SLA-190 and SLA-250 systems, features low viscosity for applications where drainage of liquid resin is a concern. It resists moisture and is used to produce visual models, working prototypes, patterns for shell investment casting, and prototype tooling inserts. **Circle No. 779**

Reverse Engineering Software

HighRES, La Jolla, CA, has introduced two 3D reverse engineering software products for FARO 6-axis portable digitizing measuring arms. HighRes Studio NT/Win 95 for FARO and Studio's plug-in option, Superspline for FARO, provide desktop software solutions for advanced manufacturing reverse engineering applications. The new interfaces work seamlessly with CADKEY and create 3D wireframe CAD drawings that translate as IGES 128 NURB surfaces, which import and export downstream into other manufacturing packages. Studio NT/Win 95 for FARO provides measurement, reverse engineering, and analysis in CAD format. The operator can fire the arm's probe in auto, semi-auto, cutplane, cutplanes point-to-plane, or point-to-axis modes. Superspline for FARO allows users to digitize by time or distance, and choose millimeters or inches as the measurement environment. **Circle No. 777**



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Commercialization Opportunities

Micromachined Force-Balance Anemometer

A micromachined force-balance accelerometer has been modified as an anemometer. The modification offers the advantages of high sensitivity, wide dynamic range, bipolar response, athermality, robustness, compactness, and low power consumption. Its overall dimensions are 2 by 2 by 0.2 cm.
(See page 39.)

Apparatus for Measuring a Weak Induced Magnetic Field

This apparatus has a sensing coil positioned in a magnetic cavity of two primary coils. The arrangement is much more compact than similar instruments used to detect metal objects underground.
(See page 46.)

First-Generation "Space Cube" Electronic-Circuit Packaging

A scheme is proposed for three-dimensional stacking and interconnection of electronic-circuit modules. This scheme provides high packaging density, without the need for interboard wiring or a back plane.
(See page 52.)

Micromachined Photodiode/Bolometer Arrays

These devices could be used throughout the spectrum, from x rays through infrared. Potential markets could be in the automotive industry for night vision, consumer electronics for security systems, the semiconductor manufacturing industry for process monitoring, and medical electronics for x-ray detection.
(See page 52.)

Multiple-Beam Transmission for Optical Communication

This approach is proposed to reduce the deleterious effects of atmospheric turbulence on free-space laser communications. The method utilizes the overlapping of mutually incoherent beams on the far field to reduce the magnitudes of signal fades and surges at the receiver.
(See page 56.)

Compact Bit-Serial VLSI Neuroprocessor for Automotive Use

An application-specific integrated circuit (ASIC) has been developed as a prototype of neuroprocessors for real-time diagnosis and control of automotive engines. The neuroprocessor responds not only to current inputs but also to recent history of inputs.
(See page 56.)

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Measuring Temperature of Glass by Multiwavelength Pyrometry

Surface and bulk temperatures are estimated from long- and short-wavelength readings, respectively.

Lewis Research Center, Cleveland, Ohio

A multiwavelength pyrometric technique estimates the surface and bulk (subsurface) temperatures of a hot glass. The multiwavelength pyrometer for which the technique was developed comprises a spectrometer plus a computer. The spectrometer can be operated in any of three wavelength ranges: 0.5 to 2.5, 0.6 to 4.5, or 2 to 14.5 μm; the range for a given measurement is generally selected according to the anticipated approximate temperature to be measured. The computer controls the spectrometer to acquire a spectrum, then analyzes the spectral data to determine the temperature.

The present technique pertains to the processing of the spectral data. Like other, related multiwavelength pyrometric techniques described in *NASA Tech Briefs* in recent years, the present technique is based partly on a modified version of Planck's radiation law. It is also based on an a distinct spectral characteristic of a typical glass; namely, that it is (1) opaque in the long-wavelength region and (2) semitransparent in the short-wavelength region of the infrared and adjacent visible spectrum to which the multiwavelength pyrometer is sensitive.

In the long-wavelength region, the radiation is emitted from the opaque surface. Planck's radiation law can be algebraically manipulated into the following equation, which is particularly useful for analyzing the spectral data:

$$\left[\frac{\ln\left(\frac{c_1}{\lambda^5}\frac{1}{L_\lambda}\right)}{c_2/\lambda}\right] - \frac{\ln\left[1-\exp\left(-\frac{c_2}{\lambda T}\right)\right]}{c_2/\lambda} = \frac{1}{T} - \frac{\lambda}{c_2}\ln\left(\varepsilon_\lambda \tau_\lambda\right)$$

where λ is the wavelength; c_1 and c_2 are constants in Planck's radiation law; L_λ is the spectral intensity at wavelength λ; ε_λ is the emissivity of the surface at wavelength λ; and τ_λ is the transmissivity, at wavelength λ, of the optical medium through which the spectrometer views the surface.

It would be convenient, for purposes of analysis, if $\varepsilon_\lambda \tau_\lambda$ turned out to be independent of wavelength. The degree to which this is true must be determined by examining the spectral data and the accuracy of the resulting interpretation. If it is true, then a plot of the left side of the equation vs. wavelength becomes a straight line with an intercept at $1/T$ — the reciprocal of the unknown temperature that one seeks to determine. For this reason, the reciprocal of the left side of the equation is often called the "radiant temperature."

In the short-wavelength region, the observed radiation originates from inside the semitransparent material. In general, there is a temperature profile $T(x)$, where x is the depth into the material. It is assumed that the spectrum of the radiation reaching the spectrometer is that of a grey body of characteristic temperature T_i, which is the bulk temperature that one seeks to determine. In this case, assuming that the wavelength is short enough to make $c_2/\lambda T >> 1$, the appropriately modified version of Planck's radiation law leads to the following equation for the reciprocal of a radiant temperature, in a form similar to that of the equation above:

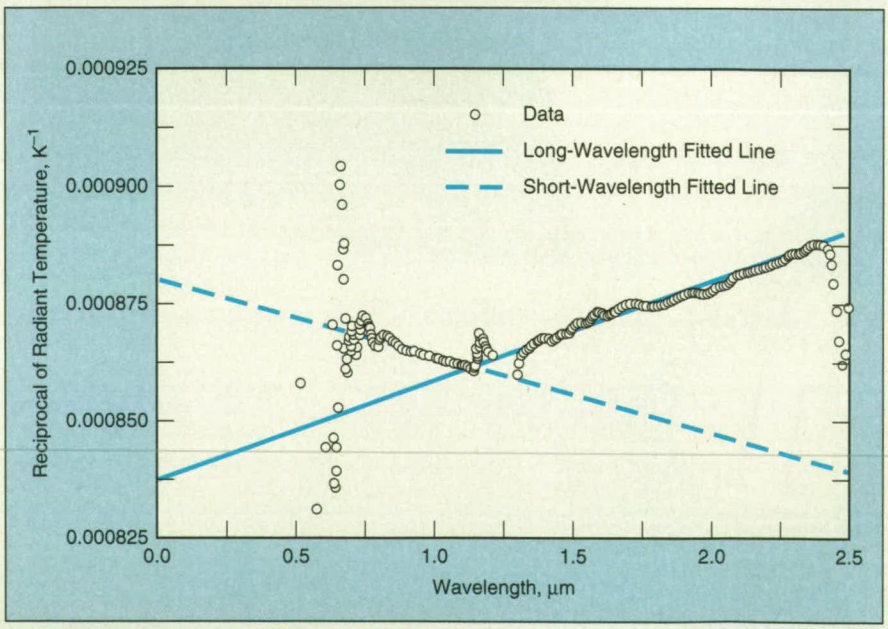
$$\frac{\ln\left(\frac{c_1}{\lambda^5}\frac{1}{L_\lambda}\right)}{c_2/\lambda} = \frac{1}{T} - \frac{\lambda}{c_2}\ln\left[I(T_i,\lambda)\right]$$

where

$$I(T_i,\lambda) = \int_0^D (1-R)a\exp\left[-ax + \frac{c_2}{\lambda}\left(\frac{1}{T_i} - \frac{1}{T(x)}\right)\right]dx$$

R is the fraction of radiation reflected back into the glass at the surface and a is the absorption coefficient of the glass.

Following reasoning similar to that of the long-wavelength case, if $I(T_i,\lambda)$ were to be independent of wavelength, then a plot of the left side of the equation vs. wavelength would be a straight



Readings of a Multiwavelength Pyrometer Were Transformed according to the equations in the text and the results plotted versus wavelength. The zero-wavelength intercepts for the long- and short-wavelength cases are the reciprocals of surface and subsurface radiant temperature, respectively.

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line with an intercept at $1/T_i$. Like the validity of the assumption of constancy of $\varepsilon_\lambda \tau_\lambda$ in the long-wavelength case, the validity of treating $I(T_i,\lambda)$ as independent of wavelength in the short-wavelength case must be determined by examination of spectral data and the resulting interpretation.

The figure is a plot of the reciprocal of radiant temperature vs. wavelength computed from multiwavelength pyrometric readings of a sample of glass heated by a propane torch. The plot clearly shows a long-wavelength region and a short-wavelength region. A straight line fit to the data from the long-wavelength region intercepts the ordinate at 0.00375 K^{-1}, corresponding to a temperature of 1,194 K; this agrees with surface temperature of 1,194 K determined by a fit to a Planck curve with an emissivity of 0.74 at all wavelengths. A straight line fit to the data from the short-wavelength region intercepts the ordinate at an ordinate that corresponds to T_i = 1,136 K. The closeness of the fit of the short-wavelength data to the straight line confirms the validity of treating $I(T_i,\lambda)$ as being independent of wavelength for these measurements.

This work was done by Daniel Ng of **Lewis Research Center.** *For further information, access the Technical Support Package (TSP) **free on-line at www.nasatech.com** under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16614.

Noncontact Measurement of Resistivity of Molten Material

The basic principle of the induction motor is utilized for a different purpose.

NASA's Jet Propulsion Laboratory, Pasadena, California

It is now possible to determine the electrical resistivity of a molten sample of a pure, electrically conductive material (a metal or semiconductor), without contact between the sample or any solid object. Once the electrical resistivity has been determined, the thermal conductivity can be estimated by use of the Wiedemann-Franz-Lorenz law. (For molten materials, thermal conductivities estimated in this way are often more accurate than are thermal conductivities determined by direct measurements, because direct thermal measurements are often distorted by convection.)

It is necessary to prevent contact with the sample because typically, the molten material can become contaminated by chemical reaction with a container or other solid object. In addition, if one seeks to characterize a deeply undercooled molten material, then contact is undesirable because it can induce crystallization and thereby terminate the undercooled state.

The present method of noncontact measurement of electrical resistivity involves electrostatic levitation and noncontact heating of the sample in a vacuum chamber. The interior of the chamber is subjected to a rotating magnetic field, which exerts a torque on the sample, in essentially the same manner in which torque is generated in an induction motor. From the values of torque measured at various tempera-

tures, one can compute the relative resistivities at those temperatures, by use of an established equation for an induction motor.

This work was done by Won-Kyu Rhim and Takehiko Ishikawa of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

NPO-20369

Noncontact Measurement of Surface Tension of Molten Material

Unlike an older noncontact method, this one works even at high viscosity.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved method of noncontact measurement of the surface tension of a molten material has been developed, partly to overcome the disadvantages of contact measurement techniques as described in the preceding article, "Noncontact Measurement of Resistivity of Molten Material" (NPO-20369). This method also overcomes the primary disadvantage of an older noncontact method in which a nonrotating levitated sample is set into vibration, the frequencies of vibrational resonances are measured, and the surface tension is determined from the known relationship among the surface tension, frequencies, and other relevant quantities. The validity of the older method is limited to viscosities less than about 1 poise. The present method works over the full range of viscosities encountered in the thermal processing of metals, glasses, and metallic glasses.

Like the method of measuring resistivity described in the preceding article, the present method of measuring surface tension involves electrostatic levitation and noncontact heating of the sample in a vacuum chamber, plus the use of a rotating magnetic field to apply torque to the sample. In this case, the application of torque is metered and timed to introduce a predetermined amount of angular momentum. The magnetic field is then turned off and the sample allowed to settle into a steady state, in which it rotates as a rigid body. The shape and the frequency of rotation of the sample are measured in the steady state. Then by use of a computational model of a rotating liquid drop, the surface tension is computed for the measured shape and frequency. This method has been verified experimentally on electrostatically levitated molten drops of aluminum and tin.

This work was done by Won-Kyu Rhim and Takehiko Ishikawa of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

NPO-20367

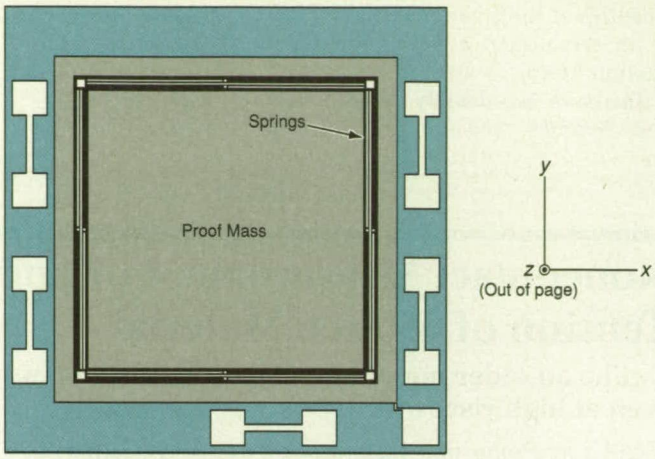
Micromachined Force-Balance Anemometer

A micromachined force-balance accelerometer is adapted to a different use.

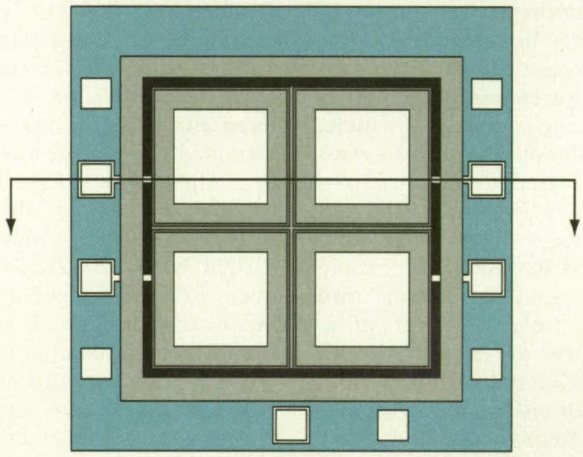
NASA's Jet Propulsion Laboratory, Pasadena, California

A micromachined force-balance anemometer has been developed by modifying the design of a micromachined force-balance accelerometer that responds to accelerations as small as 10^{-9} × normal Earth gravitation (about 10^{-8} m/s^2). The anemometer thus offers the advantages of the accelerometer; namely, high sensitivity, wide dynamic range, bipolar response, athermality, robustness, compactness, and low power consumption.

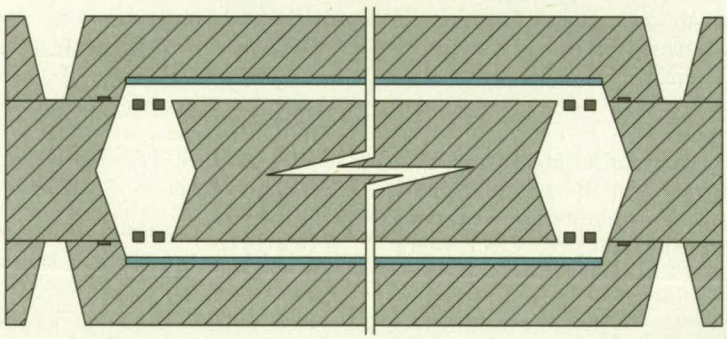
Both the accelerometer and anemometer versions of the design include a proof mass suspended on springs in a housing. The proof mass is in the form of two square plates, called "force plates," that are bonded together to



PROOF MASS AND SPRING SUSPENSION



QUAD PLATEN



PARTIAL CROSS SECTION SHOWING PROOF MASS SUSPENDED BETWEEN QUAD PLATENS

The **Proof Mass Is Suspended** on delicate springs. The spring suspension is not deflected during operation, and sensitivity is determined by precision of capacitance measurement.

form a single plate. The springs are thin beams (flexure springs) that lie alongside the edges of the proof mass (see figure). The springs are flexible enough to allow displacement of the proof mass along the z axis, but stiff enough to resist significant displacement of the proof mass along the x and y axes.

The housing includes two plates, called "quad platens," between which the proof mass is suspended on the spring flexures. In its equilibrium (non-spring-deflection) position, the proof-mass force plates lie parallel to the quad platens and about midway between them. Patterned metal coatings on the faces of the force plates and on the quad platens serve as electrodes for controlled electrostatic deflection of the proof mass and as electrodes of capacitive proximity sensors for measuring the z displacement of the proof mass. The quad platens are so named because each one is divided into four electrode areas. In the anemometer

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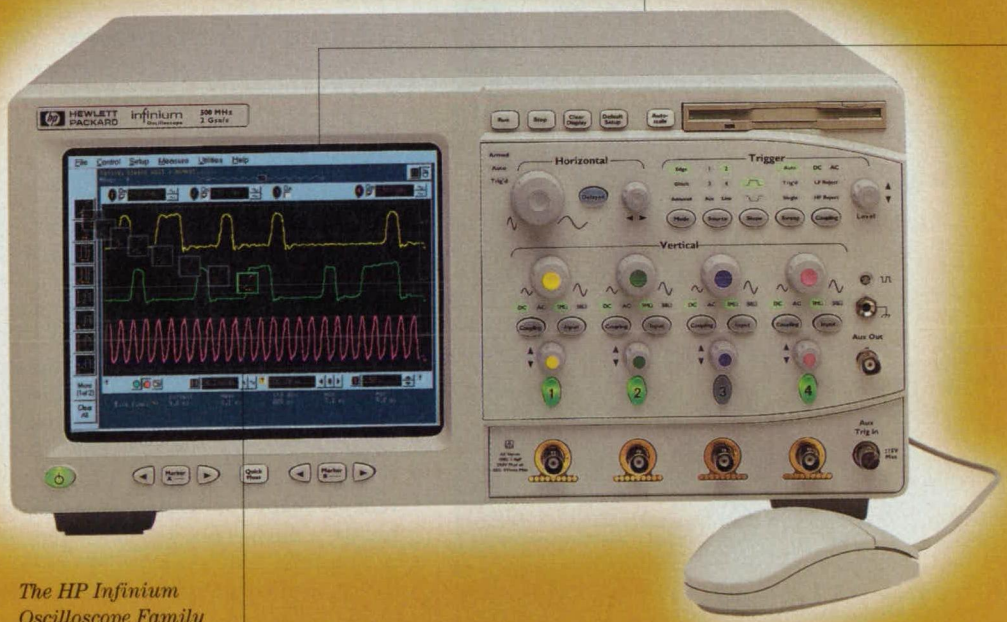

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version, quad platens are perforated (the central half of each electrode area is removed) to allow gas to flow.

In operation, the outputs of the capacitive displacement sensors are processed through a feedback control system that applies voltages between the quad platens and force plates to keep the proof mass centered at or near the equilibrium position. These voltages serve as measures of the force with which the proof mass is deflected by acceleration (in the case of the accelerometer) or by pitot static force (in the case of the anemometer).

During handling, the proof mass can be "caged" to protect its delicate spring suspension. This is accomplished by applying an electrostatic-deflection voltage to clamp the proof mass against one of the quad platens. Submicron-thick electrically insulating surface layers prevent electrical contact between facing electrodes while allowing the interelectrode gap to become small enough to enable a small battery to generate an electric field sufficient to maintain clamping.

The overall dimensions of the micromachined anemometer are less than 2 by 2 by 0.2 cm. The dynamic range is 10^6. The frequency band of high sensitivity ranges from less than 1 to hundreds of hertz.

This work was done by Frank T. Hartley and David Crisp of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*
NPO-20129

Advanced Measurement of Angle of Attack and Sideslip

Additional airdata from advanced sensors could be used to enhance performance and safety.

Dryden Flight Research Center, Edwards, California

Nearly every military and commercial aircraft in the United States today uses pitot-static probes for accurate, repeatable airdata measurements. Recently, local angle-of-attack- and sideslip-sensing capabilities have been added to these probes to satisfy requirements for advanced aircraft with extended maneuvering envelopes. Probes made in advanced shapes to satisfy these requirements have been evaluated in wind-tunnel tests at angles of attack up to 90°, with favorable results. Flight tests of the Advanced L-probe Air Data Integration (ALADIN) program, directed toward evaluating the performances of these probes, were recently concluded at NASA Dryden Flight Research Center.

The ALADIN program is a cooperative effort of Boeing Phantom Works, NASA, and BFGoodrich Aircraft Sensors Division (BFG ASD). The F-18 Systems Research Aircraft (SRA), used as the flight-test platform to evaluate these probes, provides both high-angle-of-attack- and supersonic-test capabilities. The SRA is equipped with an on-board Airborne Research Tests System (ARTS) computer, is used to perform real-time airdata calculations. BFG ASD provided two multifunction L-probes and four dual-channel pressure transducers. The transducers measured pitot and static pressure directly from the probes (1 pitot and 2 static from each probe) and transmitted these values to the ARTS

U.S. Department of the Interior

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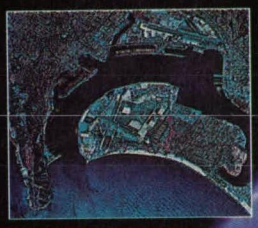


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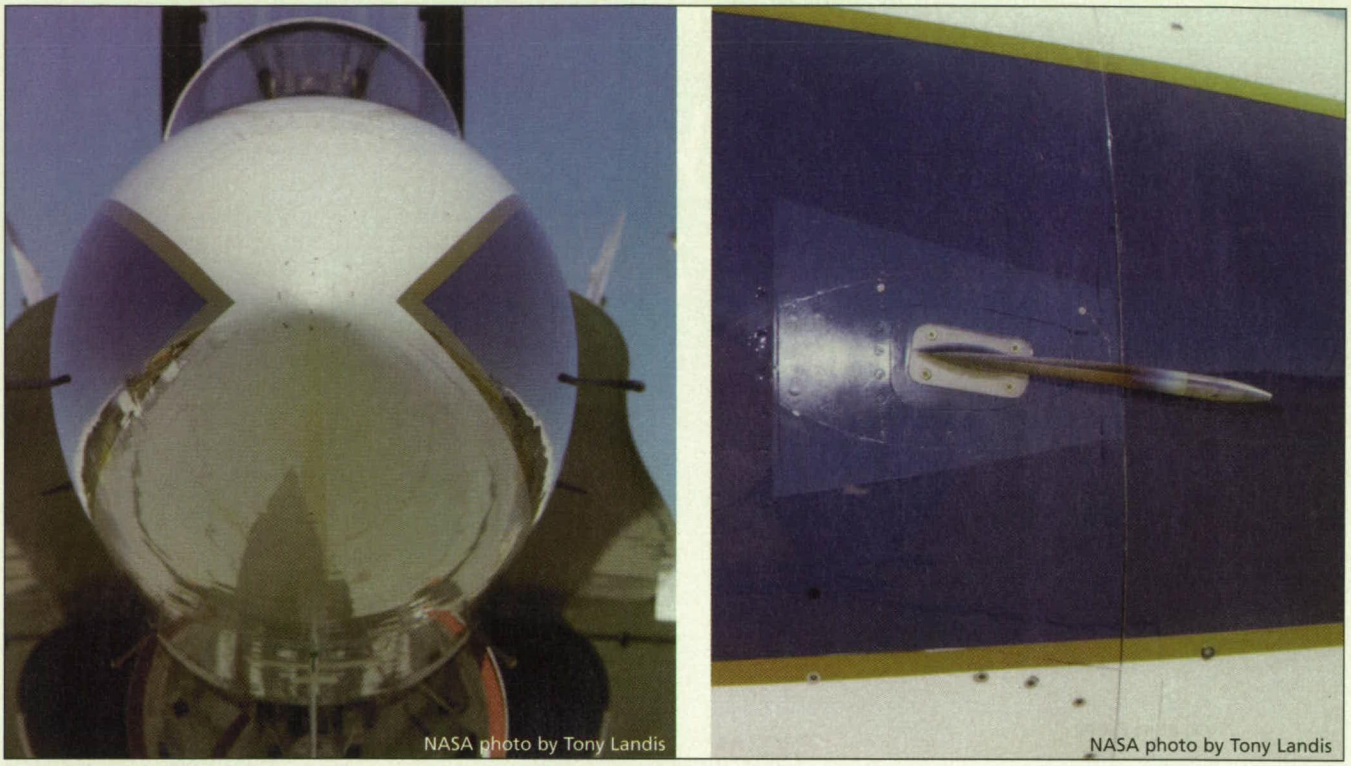


Figure 1. **Specially Shaped Fuselage-Mounted Probes** offer advanced capabilities for sensing angles of attack and sideslip.

computer via an RS-422 interface. The ARTS computer executed an algorithm developed by BFG ASD to calculate the angles of attack and sideslip using pressure differentials from the probes. Altitude, mach number, and other airdata parameters were also calculated from these pressures. The ARTS computer transmitted the measured pressure values to the SRA data-acquisition system via a MIL-STD-1553 multiplexing bus, which was telemetered to the ground. All calculations were performed in real time and compared to reference data during flight.

ALADIN flight tests were conducted in two phases. The first phase of flights was used to evaluate the performance of the probes in different regions of the SRA flight envelope. These flights also provided data to fine-tune measured-pressure-correction tables in the ALADIN algorithm for computational fluid dynamics, wind-tunnel tests, and flight tests discrepancies. The second phase of flights involved reflying the test points from the first phase and included flight maneuvers that were similar to those of the first phase but in a different region of the flight envelope. These flights provided a set of data to check the refined calibration and to further evaluate system performance.

The in-flight performance of the fuselage-mounted probes (see Figure 1) for the ALADIN system was found to be excellent over the typical aircraft flight envelope, with accurate tracking of altitude, mach number, and angle of attack.

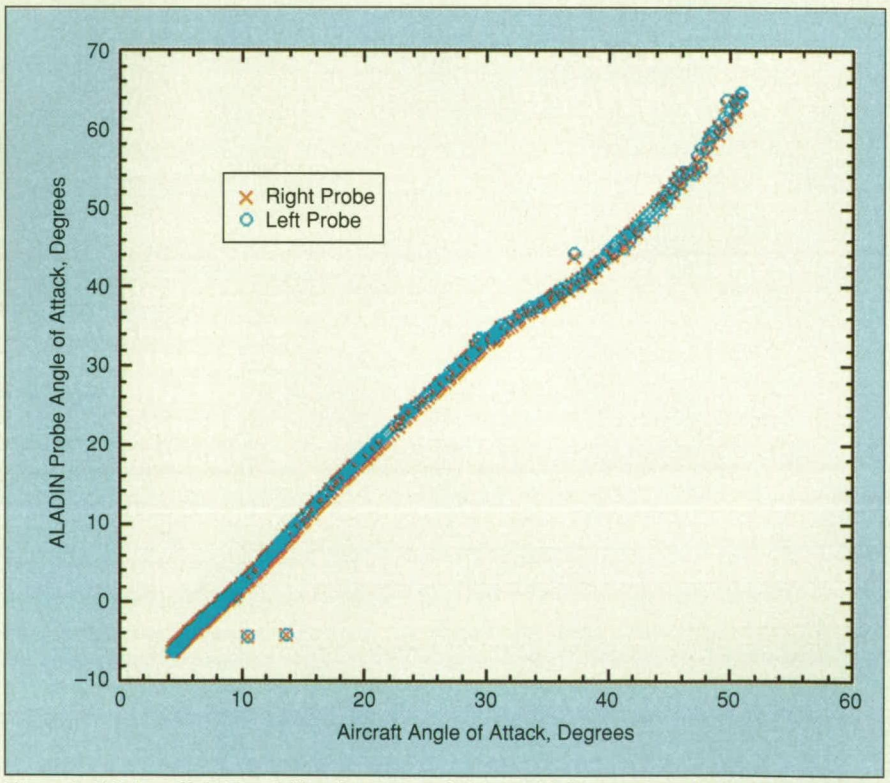


Figure 2. This is a **Flight-Test Calibration Curve** of right and left ALADIN probes at an altitude of 35,000 ft (10.7 km) and mach numbers from 0.24 to 0.74.

The BFG ASD probes and algorithm were found to be effective over a range much greater than that of the standard F-18 airdata system. Figure 2 depicts a calibration curve of probe angle of attack vs. aircraft angle of attack, as an example of the high-angle-of-attack capabilities of the ALADIN system. The ALADIN system will provide aircraft flight-control systems with more information than was previously available, thereby creating a potential to make the aircraft both safer and more capable.

Some problems identified during the flight tests are being solved with modifications to the initial algorithm. Modifications to the algorithm are being implemented by Boeing and NASA to

optimize performance for angles of attack in excess of 45°. Initial evaluation of the modified algorithm developed by BFG ASD indicates that good performance can be expected even at extended angles of attack.

This work was done by Laurie Marshall of **Dryden Flight Research Center**, *Brian Barber of Boeing Phantom Works, and Roger Foster of BFGoodrich Aircraft Sensors Division. No further information is available.*
DRC-98-64

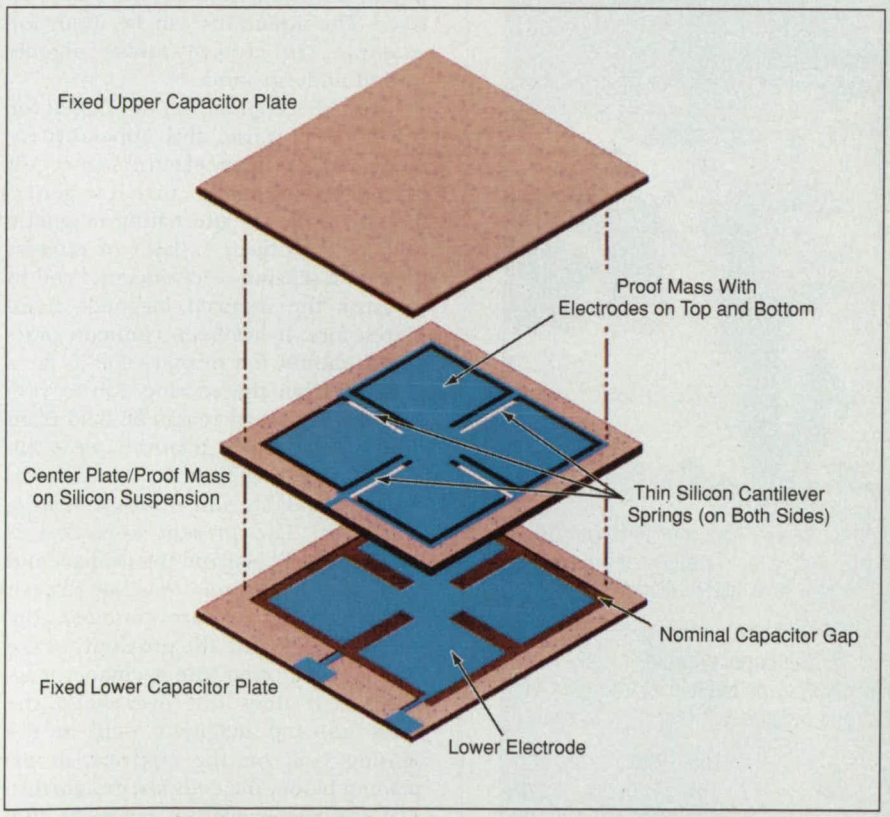
Silicon Micromachined Accelerometer/Seismometer

A compact, silicon micromachined accelerometer is specifically designed for seismologic applications.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure illustrates a silicon micromachined accelerometer currently under development that is designed specifically for seismologic applications. The device is designed for a sensitivity of 1 ng/$Hz^{1/2}$ (where g denotes the Earth's gravitational acceleration, i.e., 9.81 m/s^2) and a frequency range of 0.05 to 50 Hz. Silicon micromachining allows this instrument to be much more compact, rugged, and much lighter than commercial seismometers, without sacrificing sensitivity.

Like other seismometers, the instrument is based on a proof mass suspended by springs. Electrodes are used for capacitance-sensing of the displacement and electrostatic force rebalancing of the proof mass. These electrodes, in a differential configuration as shown in the figure, also serve to cage the proof mass during deployment. Unlike conventional seismometers, however, in this implementation, the springs, proof mass, and capacitor plates are all fabricated from single crystal silicon. Silicon has a Young's modulus close to that of stainless steel and nickel and a tensile yield strength three times higher than that of stainless steel. Fabricating the device completely in silicon allows the use of well developed silicon micromachining techniques to batch fabricate the devices. It also eliminates the noise introduced by using multiple



A **Silicon Micromachined Accelerometer** for seismologic applications is more rugged, compact, and lighter than commercial seismometers.

materials with differing thermal coefficients of expansion.

The accelerometer consists of two fixed capacitor plates with a proof-mass/capacitor-plate suspended between them. Selective wet chemical etching along with epitaxially grown, strain compensated, p^+ etch-stop layers are used to precisely and reproducibly form the thin silicon suspension and electrode gaps. Symmetry is used throughout the design to reduce sensitivity to off-axis accelerations and to simplify fabrication. The electrodes are fabricated by a thin chrome/gold metallization. The three plates are hermetically attached together while under vacuum, using low-temperature silicon-direct-bonding techniques. Evacuating the cavity around the proof mass reduces the squeeze film dampening between the plates, thereby raising the Q factor of the suspension. Current designs have a resonant frequency of 10 to 25 Hz and a normal capacitance gap of 5 to 10 μm.

This work was done by Richard D. Martin and W. Thomas Pike of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-19875 volume and number of this NASA Tech Briefs *issue, and the page number.*

Apparatus for Measuring a Weak Induced Magnetic Field

A sensing coil lies in a magnetic cavity of two primary coils.

Stennis Space Center, Mississippi

The figure illustrates an apparatus for inducing an electric current in an electrically conductive object or layer of material and measuring the magnetic field generated by the current (that is, the induced magnetic field) to obtain information about the object or layer. The apparatus can be used, for example, to detect metal objects buried underground.

Like older apparatuses developed for the same purpose, this apparatus includes (1) a primary electromagnet coil excited by alternating current to generate an excitatory alternating magnetic field in the object or layer of interest and (2) a sensing electromagnet coil to measure the induced magnetic field. Heretofore, it has been common practice to mount the primary coil as far a possible from the sensing coil to prevent the excitatory magnetic field from overwhelming the relatively weak induced magnetic field at the sensing coil; unavoidably, this results in a large apparatus. The present apparatus is more compact because the primary and sensing coils are mounted close to each other; indeed, they are mounted concentrically. Despite the proximity of the coils to each other, the excitatory magnetic field does not overwhelm the weak induced magnetic field at the sensing coil; on the contrary, as explained below, the coils are designed so that the net excitatory magnetic flux through the sensing coil is zero.

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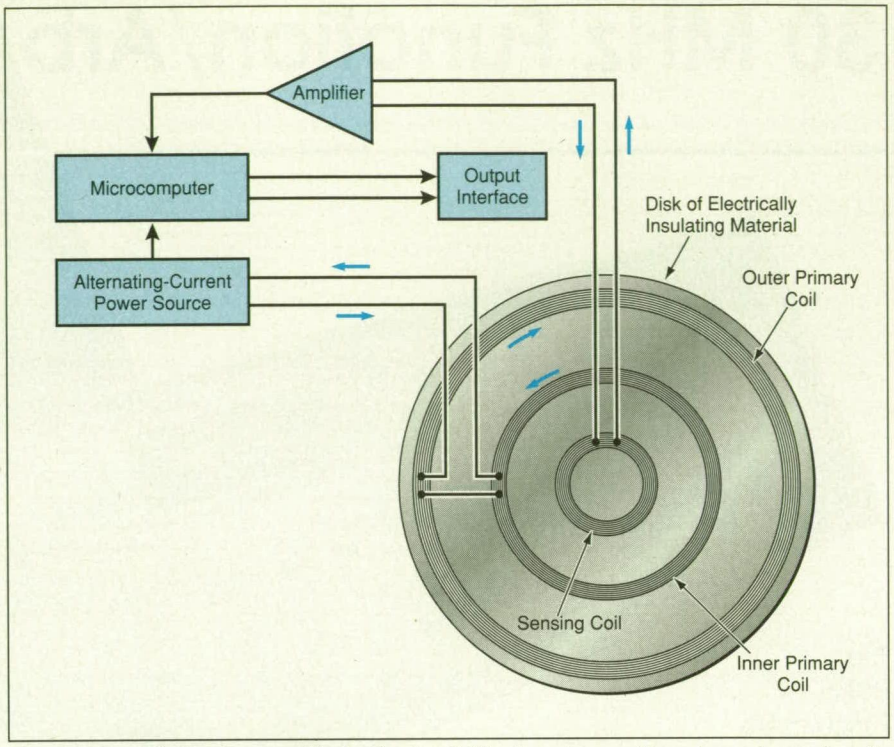
More precisely, there are two primary coils: a larger (outer) and a smaller (inner) one. The sensing coil is the smallest coil and lies within the inner primary coil. All three coils are mounted in a disk of polycarbonate or some other suitable electrically nonconductive material. The outer and inner primary coils are connected electrically in series, at opposite polarity, to a low-impedance ac power source. Thus, when power is applied, the two primary coils generate alternating magnetic fields of opposite polarity.

The magnetic fields generated by both primary coils at typical measurement distances (much greater than the diameter of the outer primary coil) are given by the well-known dipole approximation. In a typical design, the magnetic dipole moment of the outer primary coil is much greater than that of the inner primary coil, so that at typical measurement distances, the net excitatory magnetic field is dominated by the portion generated by the outer primary coil. However, near the center, where the sensing coil lies, the opposing magnetic fields from the two primary coils can be made approximately equal in magnitude, so that the net excitatory magnetic field can be made zero or nearly so within the sensing coil — in effect, placing the sensing coil in a magnetic cavity. By suitable choice of the numbers of turns and the radii of the inner and outer primary coils and the radius of the sensing coil according to established equations of electromagnetism, one can achieve a balance between the opposing excitatory fluxes intercepted by the sensing coil, so that the net excitatory flux through the sensing coil is zero.



The **Net Magnetic Flux Generated in the Sensing Coil** by the primary coils can be made zero by suitable choice of the radius of the sensing coil and the radii and numbers of turns of the primary coils.

In operation, a replica of the ac excitation is digitized and sent to a microcomputer. The electromagnetic force generated in the sensing coil by the induced magnetic field is amplified, then also digitized and sent to the microcomputer. In the microcomputer, the amplitude and phase of the signal from the sensing coil are compared with those of the ac excitation. The relative-amplitude and relative-phase information is displayed on an output interface. This information can be interpreted in terms of properties of the object or material to which the excitatory magnetic field has been applied.

This work was done by I. J. Won of Geophex Ltd. for **Stennis Space Center.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to SSC-00074, volume and number of this NASA Tech Briefs *issue, and the page number.*

Software for Automated Retesting of Electrical Connections

John F. Kennedy Space Center, Florida

The Shuttle Connector Analysis Network Automated Electrical Retest Operations (SCAN/AERO) computer program assists in the tracking, management, and automation of the retesting of electrical connectors on the space shuttle orbiters. Among other things, SCAN/AERO analyzes test data to determine the statuses of connectors and of equipment affected by them. One analysis function is identification of measurements that are outside acceptable limits for affected equipment subsystems that are not listed explicitly as being disconnected at test time. Another such function is identification of current configurations of hazardous systems that are required to be maintained in predefined configurations. A graphical user interface enables the user to select an orbiter and/or an orbiter system of interest, choose a display of current configurations, request status information, or generate an engineering report. The engineering reports generated by SCAN/AERO are meant to serve as accurate and timely retest documentation and to be distributed daily (electronically and, optionally, in printed form) to affected personnel. Concepts forged from the pioneering work of the SCAN/AERO project are being incorporated into the Checkout and Launch Control System (CLCS) that is presently under development by NASA at the Kennedy Space Center. John Wilkinson is a System Software Architect for CLCS.

This work was done by Robert D. Giffen and John Wilkinson formerly of Lockheed Martin for **Kennedy Space Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category.*

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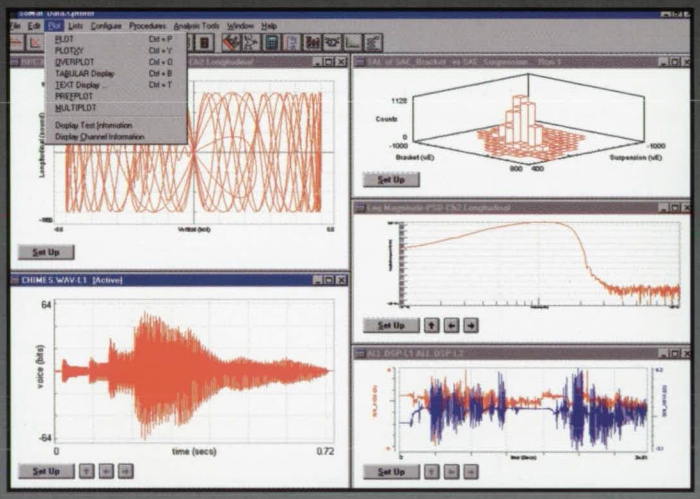
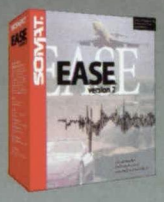
- Select from a growing list of file formats already supported under DataXplorer including: Iotech, MatLab, MTS, Nicolet, Strawberry Tree, Campbell, Sony, TEAC, Megadac, HP and text files



System Requirements

▪ Intel 486/25-based PC or higher ▪ Windows 95, Windows NT or Windows 3.1 ▪ CD-ROM drive ▪ 8 MB of RAM (16 recommended) ▪ 12 MB of hard disk space available ▪ Mouse or other Windows pointing device



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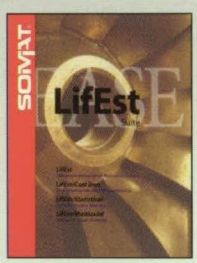
Test Planning and Data Analysis Solutions



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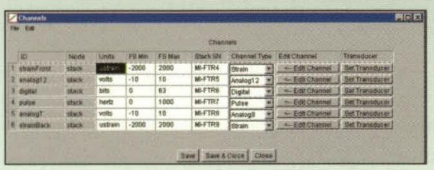

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Omega Engineering, Stamford, CT, offers the OS550 Series industrial and OEM **infrared thermometer/transmitter** that provides a choice of temperature ranges, optical field of views, and three analog outputs to feed directly into panel meters, recorders, temperature/process controllers, data loggers, data acquisition systems, or other process instrumentation. The microprocessor-based units can be mounted in any position in hostile environments.

Features include ±1% of reading accuracy, °C or °F keypad selectable, backlit LCD display, and visual and audible high/low alarm. Emissivity is adjustable from 0.1 to 1.00 in 0.01 steps via the programmable keypad. A dual display indicates current plus min, max, average, or differential temperatures.

For More Information Circle No. 743

The Model 2000-20 **scanning multimeter** from Keithley Instruments, Cleveland, OH, is a 6-1/2-digit unit with a 20-channel scanner card installed in its option slot that can be controlled from the front panel or via the RS-232 or IEEE-488 interface. Designed for production test switch and measure applications, the meter features 20-channel switching, measurement capabilities for AC and DC voltage and current, 2- and 4-wire ohms, and continuity, period, frequency, dB, dBm, temperature, and diode testing.

The meter measures DC voltage from 100nV to 1kV with 0.002 percent 90-day basic accuracy, and ohms from 100μΩ to 120MΩ with 0.008 percent 90-day basic accuracy. The instrument can scan at up to 90 channels/sec on the DCV range. A built-in limit testing function can be used to sort or grade components or assemblies based on test results.

For More Information Circle No. 744

Transducer Techniques, Temecula, CA, has introduced the HFG-45 pocket-sized **digital force gauge** designed for either handheld use via strap, or hard-mounted via four threaded holes on the back. Available engineering units are pound, ounce, kg, N, or kN for loads up to 45 pounds with full scale accuracy of 0.5% in either tension or compression.

The gauge can be used for continuous or peak capture measurements. Standard accessories include a test hook, extension rod, and compression plate. Four replaceable AA batteries are supplied, and an optional AC power supply is available.

For More Information Circle No. 751

Four series of **benchtop logic analyzers** have been introduced by Hewlett-Packard, Palo Alto, CA. The models all feature flat-panel color displays that make traces of data, timing waveforms, and analog signals easy to view and correlate. The HP 1660ES series features a built-in, two-channel digital oscilloscope with integrated triggering and the ability to display analog signals with logic analyzer data. The scope offers 500-MHz bandwidth, two gigasamples per second sampling rate, and 32K samples of memory.

The HP 1660EP series provides a built-in, 32-channel pattern generator. It provides 100 million vectors per second and a 256K-vector deep-stimulus program. The HP 1670E series includes one megasample of memory depth per channel as a standard feature to accommodate the need for deep memory in debugging. Each of the four series offers a 2-GB hard-disk drive, 1.44-MB DOS floppy drive, and RS-232 programmability.

For More Information Circle No. 745

Pressure Systems, Hampton, VA, has released the Ethernet Model 9021 turnkey, all-media **pressure acquisition system** for turbomachinery test stands, portable test systems, process monitoring, and other applications. The module can support up to 12 discrete pressure transducers, and utilizes a 10 BaseT Ethernet interface using TCP/IP protocol. DC voltage signals also can be measured on any unused input channel.

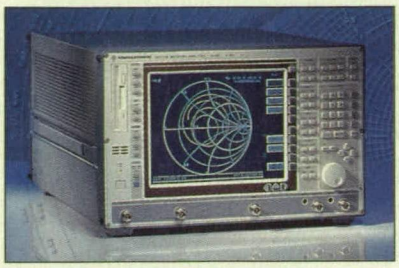
The system uses an internal 32-bit microprocessor to correct for pressure transducer zero, span, and nonlinearity errors, and performs digital temperature compensation of the sensors to reduce thermal errors. It also controls an off-line rezero or even span calibration to maintain long-term sensor accuracy. Pressure ranges from 0-5 psi to 0-10,000 psi gage or absolute are available. Measurement resolution is ±0.003% full scale, and pressure system accuracy is to ±0.10% full scale.

For More Information Circle No. 741

Fluke Corp., Everett, WA, has introduced **digital multimeter test tool accessories**, including the Fluke 80K-15 Electronic Air Cleaner Test Probe, which extends the voltage measurement capability of most digital multimeters up to 15kV. It is intended to measure the output voltage in low-energy environments. The Fluke i2000flex Current Probe is designed for current measurement on large and difficult-to-reach conductors.

The Basic TL80 electronic test lead kit consists of two test leads that are one meter in length, each with a right-angle banana connector on one end and a stainless steel test probe on the other end. The kit also contains two insulated probe tip extenders and insulated alligator clips. The Deluxe TL81 kit contains all of these items, plus two modular test leads, a modular hook-style clip test lead with banana connector, pinch-style clip test lead with banana connector, slide-on IC probe tip adapter, test lead couplers, and two bare spade lugs with banana connectors.

For More Information Circle No. 746



The ZVR/ZVC Series of **vector network analyzers** from Tektronix, Beaverton, OR, is a seven-model family that performs complex tasks such as intermodulation distortion tests and calibration procedures. The series begins with the ZVRL, a three-channel unidirectional instrument with a frequency range of 10 Hz to 4 GHz, and extends to the ZVC four-channel bidirectional tool with a range of 20kHz to 8 GHz.

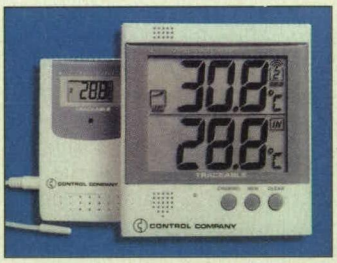
All of the instruments perform measurements including level, amplitude, phase, group delay, compression point, reflection, and others. Measurements can be stored in formats compatible with leading simulation tools. All four-channel models include two reference channels to reduce the steps required to carry out standard TOM or TRL calibration procedures. The instruments integrate via GPIB to control external signal generators.

For More Information Circle No. 749

Dwyer Instruments, Michigan City, IN, has introduced the UF10 SonicFlow **ultrasonic flowmeter** that provides flow readings of almost any clear liquid. Powered by two AA batteries or 110/240V, 50/60Hz universal power supply adapter, the meter features programmable flow rate indication in GPM, LPM, ft./sec. or m/sec., and displays total flow rate in gallons or liters. Designed for readings from 0.13 to 26 ft./sec., the meter is accurate within ±2% of reading while operating within a -32 to 113°F temperature range.

Flow transducers mount directly to a variety of pipe materials such as stainless steel, cast iron, ductile iron, PVC, copper, and concrete with diameters of 1/2" to 4-1/2". The transducer's operating temperature limits are -4 to 212°F. The meter comes with the transducer assembly, interconnecting cable, couplant, batteries, universal power supply adapter, case, and manual.

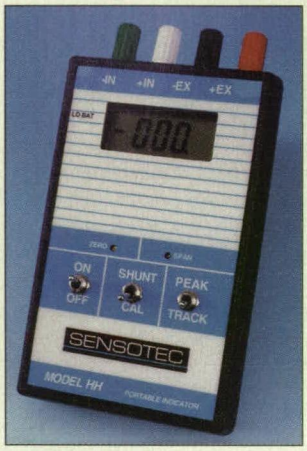
For More Information Circle No. 747



Control Co., Montgomery, TX, offers the Traceable® Radio-Signal **remote thermometer** that allows the user to read temperatures up to 100 feet away. The main digital display may be placed at a desk or bench, and the remote sensor module at a position from 65 to 100 feet away, depending on the location and wall material. The remote sensor transmits a temperature signal via radio frequency of 433 MHz to the main digital display.

The main unit permits data transfer every 30 seconds from three different remote sensor modules. Minimum and maximum memory displays allow monitoring conditions overnight, weekends, or any time period. An audible alarm may be set in one-degree increments and will sound when the temperature rises above or falls below the two set points. An external sensor has wide temperature range and reports readings to 0.1°.

For More Information Circle No. 748



Sensotec, Columbus, OH, offers the Model HH handheld **strain gage sensor instrument** that operates on a 9-volt battery and provides excitation and signal conditioning for strain gage transducers. Transducer leads are connected to the unit via four color-coded binding posts compatible with space lugs, banana plugs, alligator clips, and stranded or solid wire. The unit displays the transducer output on a 3-1/2-digit liquid crystal indicator.

The unit features potentiometer adjustments for zero, span, and scaling, and switch-selectable gain ranging to operate with any strain gage bridge transducers. The instrument measures 3.6 x 6.75 x 1.75", weighs less than 10 ounces, and is made of molded ABS impact-resistant plastic.

For More Information Circle No. 739

The Model PG5000 **digital pressure gauge** from PSI-Tronix, Tulare, CA, provides direct pressure readings up to 9,999 psi with standard accuracy of 0.25% full scale. It features a stainless steel sensor that is resistant to shock, vibration, and the effects of pulsating pressures. Options include 0.1% accuracy, auto-off, peak hold, and 0-2 vdc, 0-5 vdc, or 4/20 mA outputs.

The gauge is powered by a standard 9-volt battery, features a four-digit display with 0.5" characters, and offers an on/off switch with optional auto-off circuit. Applications include portable test gauge, process monitoring control, test stands, and laboratory use.

For More Information Circle No. 740

Pioneer Electric & Research, Wood Dale, IL, has introduced the PDT-1000 Non-Contact and PDT-2000 Non-Contact/Contact handheld **digital tachometers**. When used in non-contact mode, the instruments use a visible beam of light to measure the rotational speed (RPM) of an object from up to 14 inches away.

When used in contact mode, the PDT-2000 measures speed using one of its supplied adapters. It can measure linear surface speeds, total (count) continuously-running materials such as paper or wire, and check the calibration of counters and totalizers. The tachometers come with accessories and can be used in maintenance and machine operation applications.

For More Information Circle No. 742

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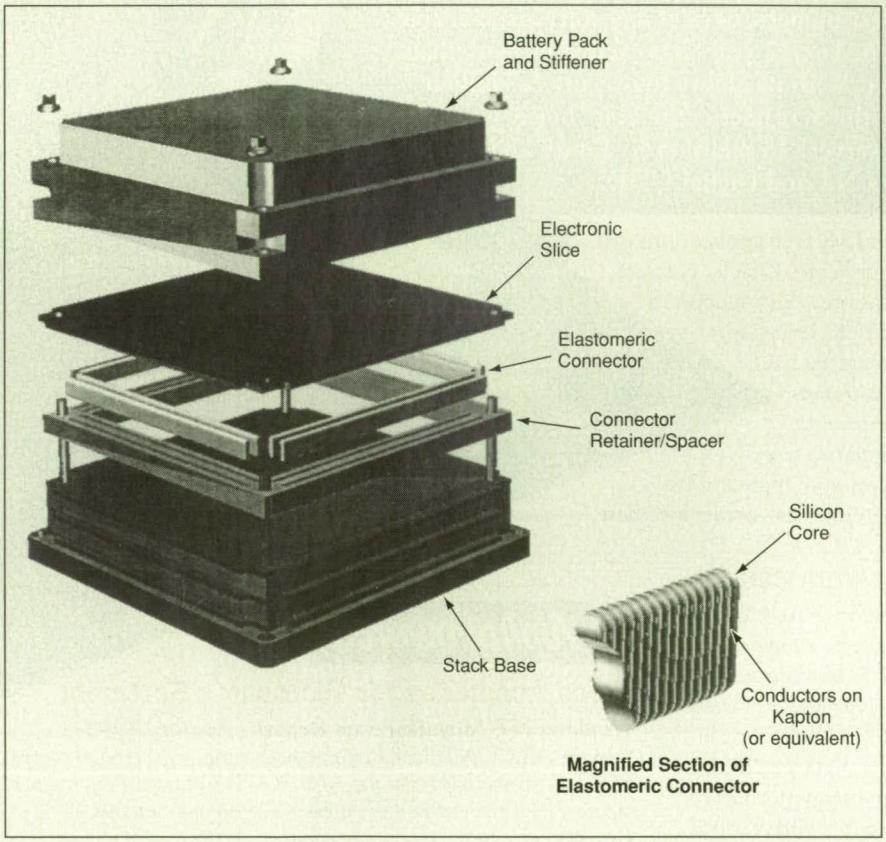
First-Generation "Space Cube" Electronic-Circuit Packaging

Modules are stacked and interconnected in three dimensions.

NASA's Jet Propulsion Laboratory, Pasadena, California

The term "space cube" denotes a scheme for three-dimensional stacking and interconnection of electronic-circuit modules. [This scheme should not be confused with a related one described in "Stackable Electronic Computer Modules and Interconnections" (NPO-19521), *NASA Tech Briefs*, Vol. 20., No. 6 (June 1996), page 33.] The figure illustrates a typical first-generation "space cube" stack. Each module in the stack is called a "circuit slice." The circuit slices are squares with edges 3.5 in. (8.89 cm) long, and with 160 electrical contacts on each edge. Electrical connections between corresponding contacts on adjacent modules are made by use of conductive strips on square elastomeric rings that are held in square retainer/spacer frames.



The **"Space-Cube"** scheme provides high packaging density, with symmetrical interconnections on all four edges of each module, and without need for interboard wiring or a back plane.

There is no particular limit on the thickness of a slice, on the material(s) of which it can be made, or the circuitry it can contain. For example, a circuit slice could be a multichip module; that is, it could contain multiple integrated-circuit chips on a printed-wiring board.

This work was done by Gary Bolotin and John Cardone of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-20236, volume and number of this NASA Tech Briefs *issue, and the page number.*

Micromachined Photodiode/Bolometer Arrays

These devices could be used throughout the spectrum, from x rays through infrared.

NASA's Jet Propulsion Laboratory, Pasadena, California

Micromachined planar arrays of detectors that could operate either as photodiodes or as bolometers have been proposed for use in detecting photons in applications in which broad spectral responses are required. The availability of either of the two modes would enable operation throughout the spectrum, from x rays through infrared. Potential markets for these devices could lie in the automotive industry (infrared-image detectors for night vision), the consumer electronics industry (infrared detectors for security systems), the semiconductor industry (process-monitoring equipment), and medical electronics (x-ray detectors).

In general, bolometers enable the detection of infrared radiation, without the need for cooling. The most com-

mon and most sensitive microbolometers now in use are based on thermistors made of amorphous semiconductors; the change in current through a thermally isolated microthermistor is indicative of the amount of absorbed radiation. Amorphous semiconductors are attractive as microthermistor materials because they are compatible with surface micromachining techniques that can be used to impart high degrees of thermal isolation. The disadvantages of amorphous semiconductors are low coefficients of thermal resistance and high levels of low-frequency ("1/*f*") noise.

In a device of the proposed type, the detectors would be single-crystal junction diodes within a micromachined structure that would provide a high degree of thermal isolation to the diodes. The diodes could be operated with forward bias to obtain the bolometric mode — usually best for detecting infrared radiation. Alternatively, the diodes could be operated with reverse bias to make them respond similarly to common photodiodes.

With respect to the functionalities of photodiodes and microthermistors, the single-crystal semiconductor materials that would be used in the proposed devices offer two important advantages over amorphous and polycrystalline semiconductors; namely, lower leakage currents and higher coefficients of thermal resistance. Exceptional thermal isolation and low thermal mass of detectors could be obtained by fabricating an array of detectors on one chip and its readout circuitry on another chip, then mating the two chips by use of hybridization techniques. For example, the detector array could be fabricated on a silicon-on-insulator chip by use of standard patterning and doping techniques, while the readout circuitry could be fabricated by standard complementary metal oxide/semiconductor processes. In the fabrication of the detector array, the thermal isolation of the detectors would be maximized and their thermal mass minimized by using surface micromachining techniques to remove most of the detector-supporting layer. The detector and readout chips could then be joined to each other by a standard technique of bonding via indium bumps on electrical-contact pads.

The sensitivity of a device of this type in the bolometric mode could be adjusted by varying the forward bias. By appropriate weighting of image data acquired in both bias modes, it should be possible to separate an image into visible and infrared parts. Depending on the selected bias, operating temperature, and spectrum of interest, a device of the proposed type may offer performance rivalling that of a quantum-well infrared photodetector (QWIP), but with a capability of operation over a wavelength range much broader than that of a QWIP. The performances of these devices may even approach theoretical limits for both thermal infrared sensors and photodiodes.

This work was done by Mark Wadsworth, Marc Foote, and Robert Beye of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category.*

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Refer to NPO-20386, volume and number of this NASA Tech Briefs *issue, and the page number.*

Improved Tuning of a Microwave Cavity for Heating Samples

This technique is applicable to both z-dependent and z-independent modes.

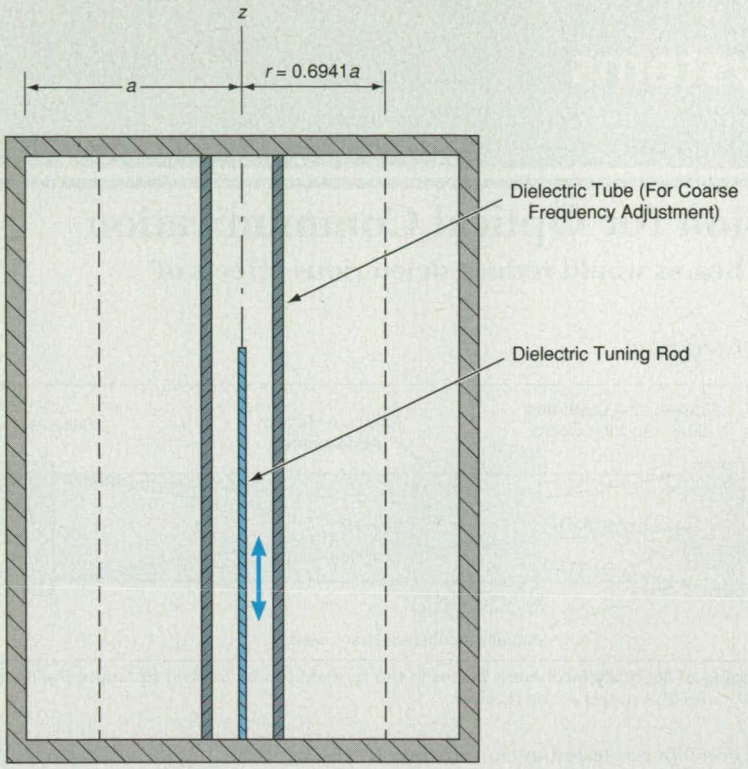
NASA's Jet Propulsion Laboratory, Pasadena, California

A technique for adjusting the resonance frequency of a single-mode round cylindrical microwave cavity has been proposed to maximize the transfer of power from a magnetron to one or more sample(s) of material that have been placed in the cavity for microwave heating. Unlike an older technique that involves insertion of a dielectric stub into the cavity from an off-axis position, the proposed technique would preserve the desired angular symmetry of the electromagnetic mode. Unlike another older technique that involves moving a plunger along the cylindrical (z) axis, the proposed technique would be applicable to *z*-independent as well as to *z*-dependent modes.

For maximum transfer of power, the resonance frequency of the cavity must be maintained within the fixed frequency band (typically 5 to 15 MHz wide) of the magnetron. The need for tuning arises because the samples exert a detuning effect: they alter the resonance frequency by an amount that increases with the real part of the permittivity of the sample material. In general, insertion of samples causes the resonance frequency to decrease from the empty-cavity value. Moreover, the permittivities of most materials vary with temperature; in a typical case, the real part of the permittivity increases with temperature, leading to a further lowering of the resonance frequency during microwave heating.

The proposed technique would exploit the detuning effect of dielectric objects. Provision would be made for adjustable insertion of one or more concentric dielectric tuning object(s) (described below). The cavity would be constructed with a radius slightly less than the value needed to match the resonance of the magnetron in the empty-cavity condition; thus, prior to insertion of any objects into the cavity, the resonance frequency of the cavity would be higher than the nominal magnetron resonance frequency. Specifically, the radius of the cavity would be chosen, according to calculations of the resonance frequencies under various conditions, so that the insertion of the samples and the dielectric tuning object(s) would cause the resonance frequency to decrease to within the tuning range of the magnetron. The position of one of the dielectric object(s) would be adjusted to maintain the resonance frequency at or near the nominal magnetron resonance frequency.

The dielectric material used for tuning should have a high melting temperature. The permittivity of the tuning material should have a real part as large as possible to maximize the achievable frequency shift and an imaginary part as small as possible to minimize absorption of microwave energy. Quartz and highly pure alumina are examples of materials that fit these criteria. Because the mag-



The **Dielectric Rod and Tube** would lower the resonance frequency of the cavity, which would have a resonance frequency slightly higher than the desired value when empty. The length of insertion of the dielectric rod would be adjusted to tune the resonance to compensate for the detuning effect of samples being heated by the microwave field at $r/a = 0.6941$.

nitude of the frequency shift is proportional to the square of the electric field, the dielectric tuning objects should be placed at or near a position or positions of maximum electric field.

The figure illustrates how the technique could be applied to a cavity excited in the TEM_{020} mode. All of the modes in the TM_{0n0} family feature electric-field maxima along the z axis and at other radial positions that depend on the mode order (n). In the TEM_{020} mode, the off-z-axis maximum occurs at $r/a = 0.6941$, where r is the radial coordinate and a is the radius of the cylindrical cavity wall. Rods of sample material could be placed symmetrically about the z axis at $r/a = 0.6941$ to intercept the electric-field maximum there for maximum heating, while a dielectric rod (optionally surrounded by a narrow dielectric tube) could be placed at the z axis to intercept the electric-field maximum there for maximum tuning effect. The fine resonance frequency would be adjusted by adjusting the length of insertion of the rod. Alternatively, a sample could be placed at the z axis and tuning rods could be positioned symmetrically at $r/a = 0.6941$.

The position of the tuning rod could be adjusted automatically by use of a feedback control system. A sensor would provide an error signal that would be used to generate commands for a motor controller. The motor would move the rod in or out by an amount that would depend on the magnitude and sign of the difference between the actual and desired resonance frequencies. A control technique that could be adapted to this application was described in "Using Vibrations to Match Impedance of a Microwave Cavity" (NPO-19500), *NASA Tech Briefs*, Vol. 20, No. 10 (October 1996), page 56.

This work was done by Martin Barmatz of Caltech and Henry Jackson of ACRO Service Corp. for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Ciruits category.*

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Refer to NPO-20409, volume and number of this NASA Tech Briefs *issue, and the page number.*

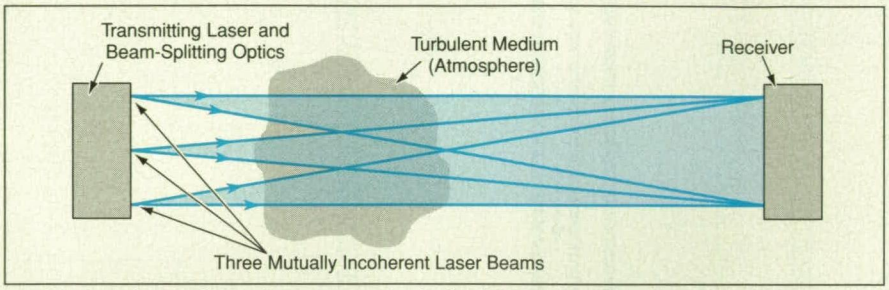
Multiple-Beam Transmission for Optical Communication

Superposition of mutually incoherent beams would reduce deleterious effects of atmospheric turbulence.

NASA's Jet Propulsion Laboratory, Pasadena, California

Multiple-beam transmission has been proposed to reduce the deleterious effects of atmospheric turbulence on free-space laser communications — especially on uplinks from ground stations to Earth-orbiting satellites. The deleterious effects in question are signal fades and surges associated with scintillation, beam broadening, and beam wander. These effects are caused by amplitude and phase fluctuations that, in turn, are caused by turbulence-induced spatial and temporal fluctuations in the index of refraction of air.

The basic principle of the present multiple-beam-transmission concept is one of incoherent superposition. The beam from the transmitting laser would be split into two or more beams, the optical path lengths of which would differ from each other by more than the laser coherence length. The beams would be transmitted to the receiver from points separated laterally by more than the optical coherence length of the turbulence cells in the atmosphere (for a wavelength of 0.5 μm, this length is about 10 cm). The overlap of the beams in the far field would therefore be characterized by temporal and spatial incoherence among the beams, with consequent stochastic smoothing that would reduce the magnitudes of fades and surges in the signal arriving at the receiver.



Overlapping of Mutually Incoherent Beams in the far-field can be utilized to reduce the magnitudes of signal fades and surges at the receiver.

The concept was tested in experiments on optical communication between a station at the Table Mountain Facility near NASA's Jet Propulsion Laboratory and a laser-communication apparatus aboard the Japanese ETS-VI satellite. In these experiments, the laser beam from the transmitter on the ground was split, variously, into two or four beams that were directed up to the satellite. Once a signal-tracking loop in the satellite was activated, the laser transmitter aboard the satellite transmitted a downlink signal to the ground station. In spite of some difficulty in deconvolving atmospheric effects from pointing errors and spacecraft vibration, analysis of data from the experiments revealed significant improvements in uplink reception with multiple uplink beams. Downlink signal fluctuations were attributed to pointing jitter, suggesting the need for highly accurate pointing to establish a stable communication link.

This work was done by James Lesh and Keith Wilson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category.*

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Compact Bit-Serial VLSI Neuroprocessor for Automotive Use

Efficient utilization of hardware makes for compactness.

NASA's Jet Propulsion Laboratory, Pasadena, California

An application-specific integrated circuit (ASIC) has been developed as a prototype of neuroprocessors for real-time diagnosis and control of automotive engines. The application of this ASIC was previously reported in "Neuroprocessor for Detecting Misfire in an Automotive Engine" (NPO-20044) *NASA Tech Briefs*, Vol. 21, No. 12 (December 1997), page 60. The neuroprocessor is configured as a recurrent neural network, which differs from a conventional feedforward neural network in that the inputs to some of the neurons can include feedback signals in the form of time-lagged, weighted outputs from other neurons. Thus, the neuroprocessor responds not only to current inputs but also to the recent history of inputs.

As was previously reported, the neuroprocessor ASIC is implemented in high-speed complementary metal oxide/semiconductor (CMOS) very-large-scale integrated (VLSI) circuitry with a bit-serial architecture. By employing bit-serial techniques, this architecture makes for compactness and cost-effectiveness because (1) it entails fewer interconnections and less hardware than does bit-parallel architecture and (2) efficiency is

increased through the periodic, repetitive use of the same circuitry in a time multiplexing scheme to implement successive layers in the neural network. Because the same neurons are reused in successive layers of the neural network, the total number of neurons need not exceed that of the largest layer. This architecture also affords flexibility to realize different neural-network configurations for different diagnostic or control functions; that is, multiple tasks can be performed in rapid succession, using the single neuroprocessor ASIC, by loading the synaptic-connection weights for each task at the time of that task.

The ASIC includes a module containing 16 neurons, a global controller, a read-only memory (ROM) containing a lookup table that specifies a bipolar sigmoid activation function of a neuron, a random-access memory (RAM) that serves as a register of neuron states, and a RAM containing synaptic weights (see figure). In this physical VLSI realization, each neuron receives, as inputs, synaptic weights and activation-function values from input nodes or neurons of a preceding layer in bit-serial fashion; each neuron responds by performing multiplication-and-accumulation operations that yield the value of the activation function for the given inputs.

The global controller generates the control logic and orchestrates the movement of data, as needed, to enable the rest of the ASIC to perform the required task. When a "run" command is issued, the global controller provides control signals to the 16 neurons, the RAMs, and the ROM to proceed with the desired neurocomputation. Input activations and synaptic weights are read out of the neuron-state and synaptic-weight RAMs, respectively, and sent to the neurons. Upon completion of a forward pass through the module of neurons, the global controller returns to an idle state, awaiting receipt of the next "run" command.

This work was done by Raoul Tawel of **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category.*

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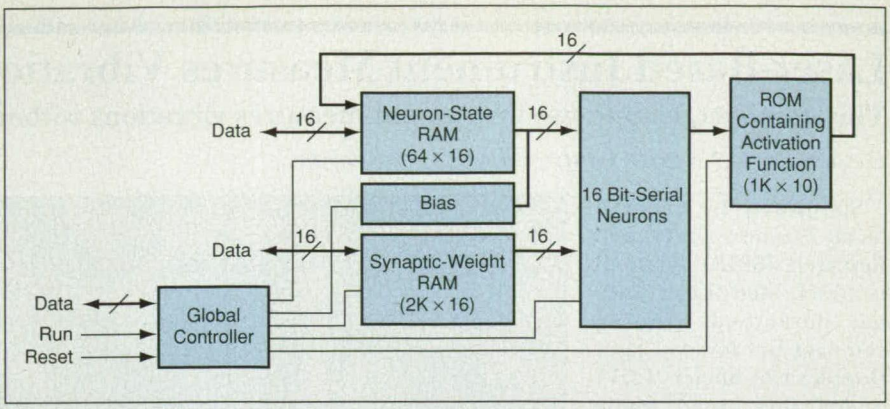


The **Prototype VLSI Neuroprocessor** functions as a recurrent neural network. It features a bit-serial architecture that affords compactness, cost-effectiveness, and flexibility of configuration for a variety of tasks.

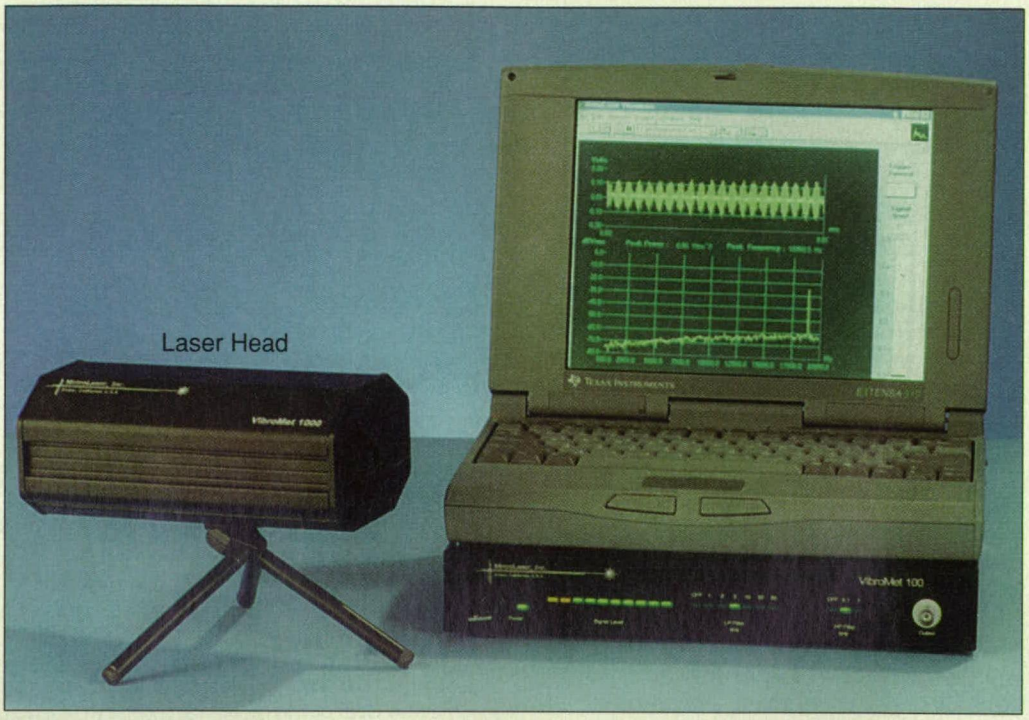
Laser-Based Instrument Measures Vibration at a Single Point

This compact, easy-to-use instrument measures vibrations without contact.

Dryden Flight Research Center, Edwards, California

Sponsored by a NASA Small Business Innovation Research (SBIR) Phase II contract, MetroLaser, Inc., has developed a novel, compact and low-cost laser Doppler vibrometer (LDV) under the brand name VibroMet. This LDV is a turnkey system for noncontact measurement of vibration at a single point on any vibrating structure. The system consists of two parts: a laser head and an electronic control unit (see figure) that are connected by a flexible electrical cable. Some of the notable features of the system include the following:

- Simple "point and shoot" operation for object distances from a few centimeters to 3 meters;
- Detection of signals from



This **Laser Doppler Vibrometer** is a turnkey system for noncontact measurement of vibration at a single point.

untreated, low-reflectivity surfaces, including black paper;
- A compact laser head that measures 2 by 3.5 by 6 in. (5.1 by 8.9 by 15.2 cm) and weighs less than 2 lb (<0.9 kg);
- Measurement over a wide dynamic range.

The frequency and velocity ranges of the standard VibroMet are 5 Hz to 80 kHz (at 3 dB) and 10 μm/s to 0.1 m/s, respectively. The detection ranges are expected to increase to the intervals from 2 Hz to 2 MHz and 80 μm/s to 1 m/s, respectively, in the next generation of this system.

The laser head is based on a novel configuration (patent pending) in which a diode laser and an acousto-optic modulator are the only optical elements (there are no mirrors or beam splitters). This simple optical configuration results in a robust instrument that is easy to align and straightforward to manufacture. The laser head contains all the electronic circuitry for amplification and demodulation of the Doppler vibration signal. The electronic control unit includes dc power supplies, a radio-frequency driver, a signal-strength display, and selectable signal-conditioning circuits for use as antialiasing filters.

This system can be used in many applications; examples include testing of prototypes, monitoring the health of machinery, and quality control on assembly lines. Recently, MetroLaser collaborated with the Department of Civil and Environmental Engineering of the University of California at Irvine in performing a series of experiments to explore the utility of an LDV in detection of earthquake-induced damage. The VibroMet was used to measure the natural vibrational frequencies of concrete structures that are representative of highway bridge supports. The results of the experiments conclusively demonstrated that this system can accurately measure damage induced by simulated earthquakes, which may not be detectable by visual inspection. The results of the experiments also demonstrated that natural frequencies in concrete structures can be measured by use of random excitations, such as those from vehicular-traffic vibrations or wind. Therefore, monitoring of highway bridges for damage induced by earthquakes can be accomplished quickly and without interruption of service by use of this system.

A survey by means of this system is being planned for 70 new bridges in the soon-to-be-opened Eastern Corridor Toll Road in Orange County, California. Tracking the degradation of the bridge supports over time and especially after earthquakes will both validate this system for widespread use and provide safety engineers with valuable information.

In addition to having expanded measurement ranges as mentioned above, the next generation of this system will be more compact. It is envisioned that the system will eventually be powered by batteries and the size of the laser head will be reduced to that of a pen.

This work was done by De Yu Zang, James Millerd, David Rosenthal, Eric Johnson, and Cecil Hess of MetroLaser, Inc., and Matt Tonge, an independent consultant, under an SBIR contract monitored by **Dryden Flight Research Center.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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(949) 553-0688

Refer to DRC 098-067, volume and number of this NASA Tech Briefs *issue, and the page number.*

Program for Conceptual Design of an Attitude-Control System

A report describes the ACS Design Tool — a Macintosh- and PC-based computer program for evaluating conceptual designs of a spacecraft attitude-control system (ACS) within a computation time of about 15 minutes. Services provided by the program include computation of ACS performance and sizing of ACS equipment for 3-axis gravity-gradient- and spin-stabilized spacecraft; computation of pointing jitter; computation of star-acquisition probabilities; computations of inertial quantities; radiation-shielding computations; transformation of attitude coordinate frame; conversion of units of measure; estimation of cost of an ACS at either of two different levels of complexity and accuracy; information on project definitions and standards; and data bases on celestial bodies, thrusters, ACS equipment lists, and costs for JPL missions. Developed within the Microsoft Excel software environment, this program provides easy-to- use graphical user interfaces (GUIs), including pull-down menus, scroll/increment buttons, and general buttons. The program consists of six collections of subprograms, which are summarized in the report. The report includes examples of GUI displays for all of the subprograms.

This work was done by Kenneth Lau, Edward Swenka, G. Mark Brown, Edward Mettler, Tooraj Kia, Samuel Sirlin, David Bayard, Fred Hadaegh, Edward Wong, John Lai, and Brian Cox of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "ACS (Attitude Control Subsystem) Conceptual Design Tool (software program)," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category. NPO-20298*

Program Computes Flightpaths From Point Radar Sightings

A computer program estimates great-circle-arc (GARC) flightpaths of multiple aircraft, given time-tagged point locations from radar sightings of the aircraft. The problem of generating such estimates is called a "clustering" problem, and is solved in this instance by use of a neural-network clustering algorithm. Points are considered in pairs; the likelihood that any two points are on the flightpath of the same aircraft is quantified by an "association value" based on the flight dynamics of the aircraft. The program implements a Boltzmann machine, the sparse architecture of which provides for only partial satisfaction of the constraints of a cost function; this, together with a special graphical interface, serves as an aid in determining GARCs. The neural-network algorithm operates on all points simultaneously and performs a global optimization through simulated annealing; thus, it is in many instances superior to both traditional clustering algorithms that operate on points sequentially, and to other neural-network algorithms that perform local optimization. The neural network can also readily be implemented in hardware.

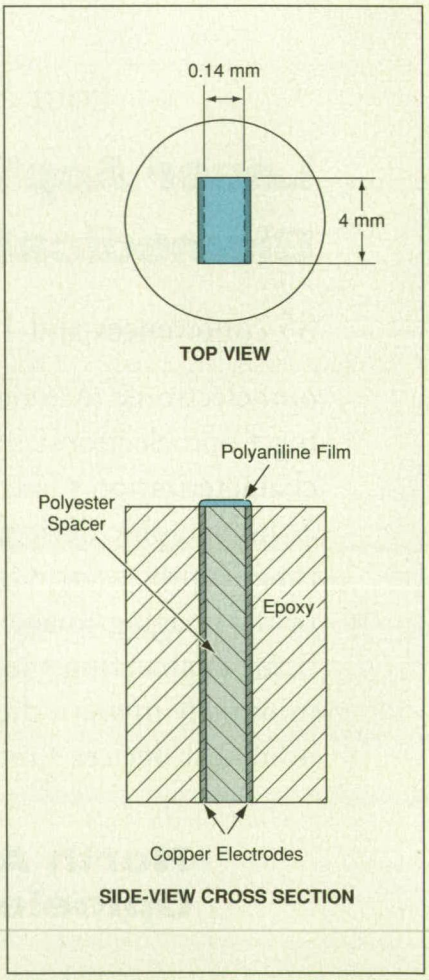
This work was done by John Spagnuolo, Jr., of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Software category. NPO-20288*

Acid/Base Sensors Based on Poly(aromatic amine) Films

Inexpensive sensors can measure concentrations in the sub-parts-per-million range.

Stennis Space Center, Mississippi

Chemiresistors containing poly(aromatic amine) films have been invented to satisfy a need for simple, inexpensive sensors for real-time measurement of parts-per-million and possibly lower concentrations of acidic and basic gases in air. These sensors could also be used to measure concentrations of acids and bases in aqueous solutions. Likely applications could include measuring concentrations of HF, HCl, HBr, and HI near incinerators in which halogenated hydrocarbons are burned; measuring concentrations of HF in and near semiconductor-processing plants; and measuring concentrations of HCl from rocket-engine exhausts. In these applications, the chemiresistors could



This **Prototype Sensor** was fabricated to demonstrate basic principles of the invention and is not optimized for any particular application. The sensory film was cast from a 1-percent solution of the emeraldine base form of polyaniline in N-methylpyrrolidone. The film was doped by exposure to aqueous HCl solutions at various pH levels.

supplant larger, heavier, more-expensive instruments that are difficult to use, do not respond in real time, and are often insufficiently sensitive.

Chemiresistors have been described in a number of previous articles in *NASA Tech Briefs*. A chemiresistor comprises a pair of metal electrodes in contact with a thin, electrically conductive polymeric film on an electrically insulating substrate. The electrical resistivity of the film increases or decreases reversibly when the film is exposed to certain chemicals. In a chemiresistor of the present type, the film is made of a poly(aromatic amine), the resistivity of which decreases upon exposure to acids in both the vapor and aqueous phases. In addition, the color of a poly(aromatic amine) varies with the acidity of its environment; thus, in principle, one could deposit a poly(aromatic amine) on the end of an optical fiber and monitor the concentration of acidic gas by measuring the optical absorption spectrum from the opposite end of the fiber.

Examples of suitable poly(aromatic amine)s include the following polymers in all of the various oxidation states in which they can exist: (1) polyaniline; (2) such derivatives of polyaniline as poly(ethylaniline), poly(butylaniline), and poly(orthotoluidine); and (3) the electroactive copolymers of polyaniline with its derivatives. Protonation (doping) or deprotonation (de-doping) of the –N= sites in these polymers leads to characteristic conductivity-versus-concentration curves that can be calibrated to obtain reliable, instantaneous readings of acid/base concentrations.

A sensor of this type could be made in a variety of ways. For example, a poly(aromatic amine) film could be cast from solution on an insulating substrate to which electrodes were previously attached (see figure). Instead of a pure poly(aromatic amine), the film could consist of a poly(aromatic amine) sensory component dispersed in a nonsensory matrix of poly(methyl methacrylate), poly(vinyl chloride), or polystyrene. An array of sensors, wherein the electrode spacings, film thicknesses, and or doping levels of the sensors would differ, could be fabricated for use quantitating various acids and bases in various concentration ranges.

The doping level of a poly(aromatic amine) film can be adjusted, during fabrication, by any of a variety of chemical or electrochemical treatments. For example, a film initially in the emeraldine base (low-conductivity, blue) state can be protonated to an emeraldine salt (high-conductivity, green) state by equilibrating the film with an aqueous protonic acid. For another example, a polymeric dopant can be incorporated during polymerization or during a post-polymerization treatment.

Of the poly(aromatic amine)s, polyaniline is especially attractive, not only because it has suitable physical and chemical properties, but also because its monomer is relatively inexpensive; thus, it should be possible to manufacture relatively inexpensive (even disposable) sensors for deployment over large areas and for personal monitoring badges.

This work was done by Guang-Way Jang of Gumbs Associates, Inc., for **Stennis Space Center**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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(908)257-9049

Refer to SSC-00069, volume and number of this NASA Tech Briefs *issue, and the page number.*

Improved Anode Design of Rechargeable Li-Ion Cells

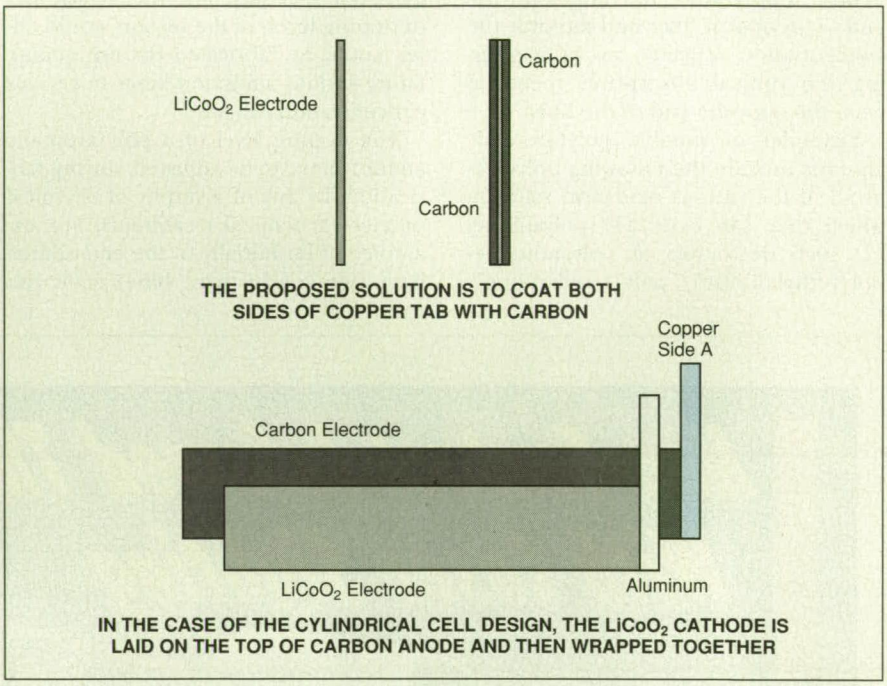
Proposed modifications would inhibit formation of lithium dendrites on the surface of the anode tab.

NASA's Jet Propulsion Laboratory, Pasadena, California

Several modifications of the basic design of carbon lithium-intercalating anodes with copper current collectors in rechargeable lithium-ion electrochemical cells have been proposed. These modifications are intended to prevent or at least retard the internal short-circuiting and consequent premature failure that can be caused by lithium dendrite and copper dendrite.

A rechargeable lithium-ion electrochemical cell that contains a carbon anode with a copper current collector is susceptible to internal short-circuiting by either or both of two mechanisms: (1) During overcharge, lithium dendrites can grow to form conductive anode-to-cathode bridges. (2) During overdischarge, the copper current collector becomes dissolved and copper becomes redeposited elsewhere, forming a conductive anode-to-cathode bridge. In experimental cells that have become short-circuited, lithium dendrites have been found to grow on the anode tabs (which are parts of the copper current collectors), and copper deposits have been found to grow in the separators adjacent to the anode tabs.

One of the proposed modifications is to cover each anode tab, which directly faces the cathode active material, with active carbon anode material (see figure). The carbon covering would prevent direct exposure of the copper tab material to the active cathode material. The carbon covering would reduce the lithium activity at the surface of the tab sufficiently to prevent the deposition of lithium there. Another proposed modification is to orient the cathode separator pores perpendicular to the anode separator pores.



The **Anode Tab**, which directly faces the cathode active material, would be coated with carbon anode material to inhibit electrochemical processes that contribute to internal short-circuiting.

This work was done by Chen-Kuo Huang of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Matericls category.*

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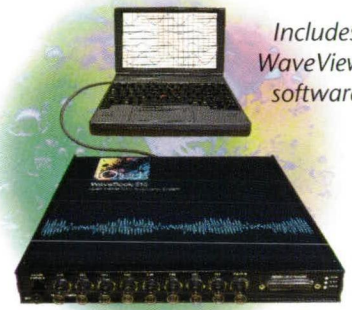

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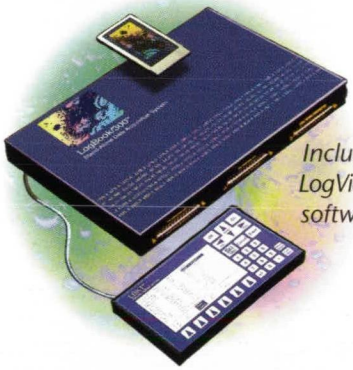

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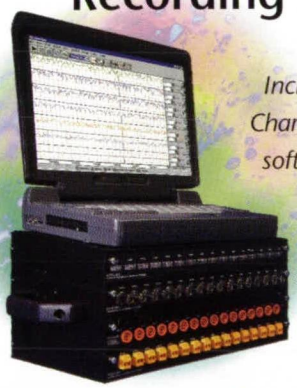

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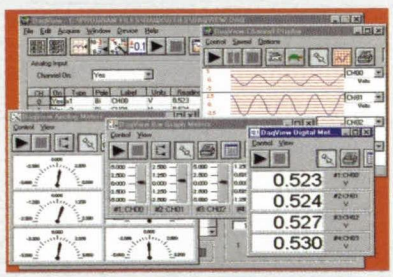

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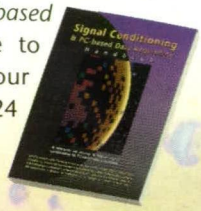

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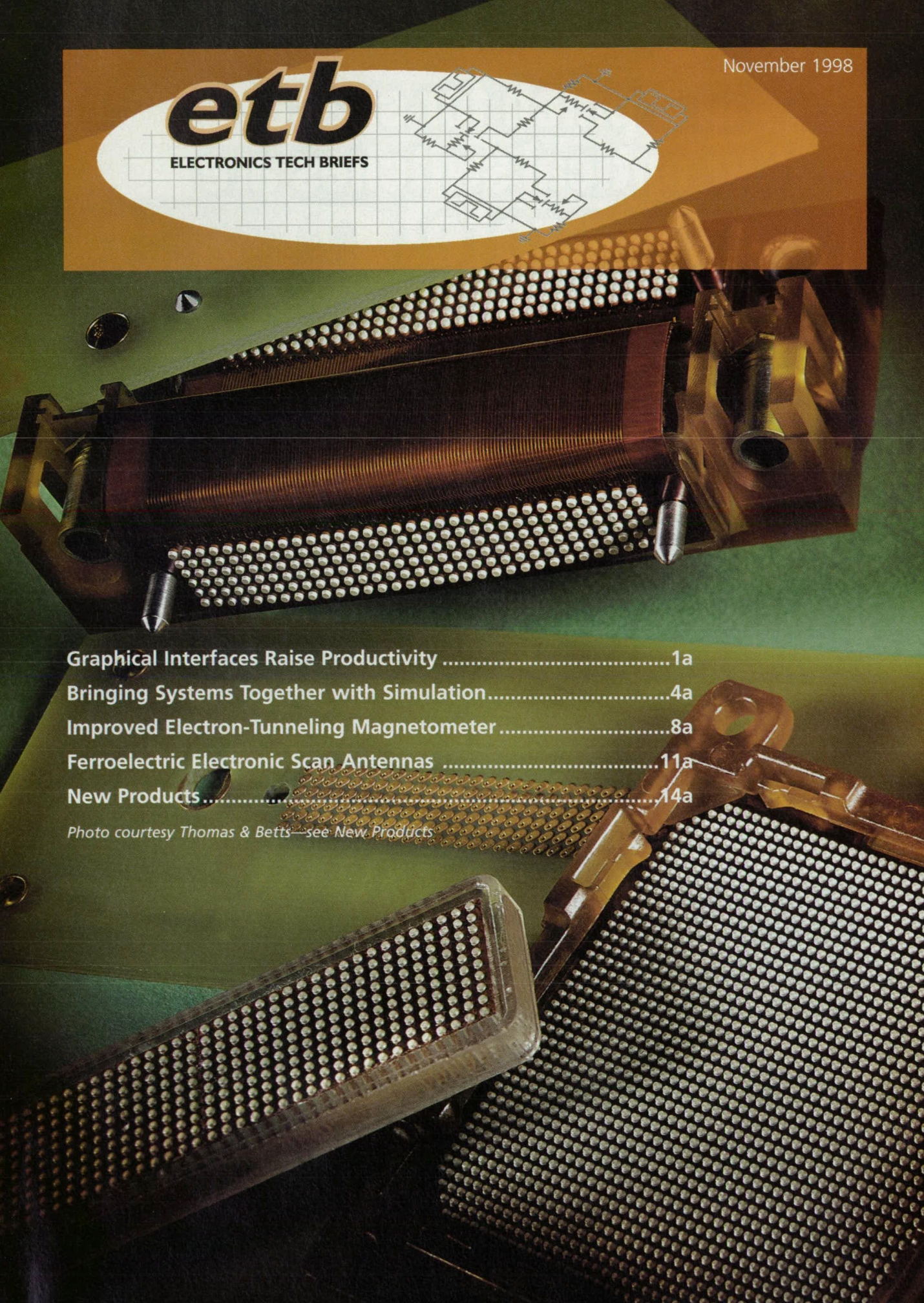

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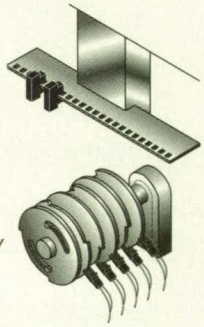

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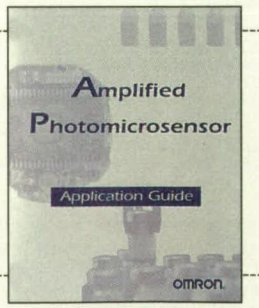

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Graphical Interfaces Raise Productivity

Electronic test and measurement products get a boost from graphical user interfaces.

Figure 1. Screen shot of drag and drop measurement sequence.

While user interfaces for test and measurement equipment vary widely from product to product, most can be categorized as one of three general types:

- dedicated (fixed-function) controls alone;
- dedicated controls augmented by reprogrammable soft keys; and
- dedicated controls supported by a graphical interface featuring menus, dialog boxes, and other graphical control elements.

Over time, as equipment has grown more complex and advanced technology more accessible, there has been a progression from the former to the latter interface types. Dedicated controls (knobs, buttons, and other switches) were developed first, since they were a natural means for controlling equipment that either delivered basic functionality, or lacked the microprocessor control necessary for more advanced interfaces.

As equipment became more complex and microprocessor control more common, soft keys were introduced as a means of reducing front-panel clutter. Soft keys work by overloading functionality onto a limited number of physical keys, thereby creating "virtual keys" with functionality dependent on the current key assignments. The trade-off is that navigation through the key tree becomes difficult once more than one or two levels of assignment are involved. As equipment complexity has made soft-key-based interfaces ever more challenging to use, equipment vendors are beginning to introduce products featuring true graphical interfaces like those found in computer products.

While the first two interface types have their advantages, graphical user interfaces (GUIs) are rapidly becoming the mechanism of choice for interacting with modern feature-laden electronic test equipment. Compared to their soft-key-based predecessors, graphical interfaces offer several significant benefits.

One of these is familiarity. Given their extensive use of computer systems, nearly all engineers and scientists are familiar with some sort of "windowed" user interfaces. Whether they are based on PC, UNIX, or Macintosh platforms, all of these interfaces make use of pointing devices, menus, dialog boxes, toolbars, and various other graphical controls. Consequently, when users move from their computers to GUI-based test equipment, they are then able to leverage their understanding of these interface elements. When learning is transferred this way, it eliminates the need to learn (or relearn) another interface, resulting in increased productivity.

Expanding help systems

On-line help is another key benefit associated with graphical interfaces. While some soft-key-based instruments contain help systems, they are typically limited to basic instructions on how to use the instrument's front-panel keys. The help systems associated with graphical interfaces, however, are capable of delivering much more functionality, including context-sensitive help, glossaries, indexes, and topic searches. Advanced features can include setup guides, task wizards, and detailed technical expertise on critical measurement topics.

For example, a help system for an oscilloscope can contain detailed background information on the theory of fast Fourier transforms (FFTs). Rather than merely instructing the user on which control to manipulate to invoke an FFT, this information can serve as a broad context for how the measurement fundamentally works; how best to use it in light of other available alternatives; what the relationships are between such key quantities as frequency resolution, sample rate, and

Figure 2. Screen shot showing translucent dialog box.

memory depth; and so on. Access to online help increases productivity because the information is all in one place, is extensively cross-referenced, and is inherently in context. Additionally, it can never be lost or misplaced the way a hard-copy volume can.

GUIs offer two other significant advantages for increasing test and measurement productivity: the capability for more natural control metaphors, and the capability for providing multiple control methods and customization facilities to accommodate different user preferences. The Infinium oscilloscope from Hewlett-Packard (a 1997 *NASA Tech Briefs* Product of the Year finalist) showcases these advantages.

These scopes are based on an industry-standard X86 computer and the Windows 95™ operating system. They provide several natural control metaphors by allowing users to interact directly with signal waveforms and markers displayed on the screen. For example, to reposition a waveform (*i.e.*, change its vertical offset or horizontal delay), the user simply clicks the

mouse over the waveform and moves it to the desired position. To change the overall scale on the display, the user draws out a zoom box and clicks inside it. To apply a measurement to a signal, the user selects an icon depicting that measurement and drags it to the region of interest on the signal. This process is shown in Figure 1. These operations are natural because they are waveform-centric, and waveforms are the primary quantity of interest in an oscilloscope. So rather than force the user to adapt to the instrument's control model, the instrument lets users interact with it in ways they expect and prefer.

Matching user preferences

Indeed, these oscilloscopes include several capabilities that allow common operations to be performed in various ways to accommodate user preferences. For example, measurement tasks can be accomplished through menu selections, toolbar controls, right-click shortcuts, and direct graphical operations. An innovative preference is for the rendering of dialog-box backgrounds. Dialogs may be displayed conventionally with opaque backgrounds, or shown transparently or translucently—such that changing waveform information is revealed through the background of the dialog to some extent. Again, this reflects the importance of waveform viewing in an oscilloscope. An example of a translucent dialog in action is shown in Figure 2. Other flexibility provisions include color customization, mouse button assignment, and the capability to control how many dialogs may be simultaneously active.

Hewlett-Packard didn't develop the Infinium scope family in a vacuum. On the contrary, the company spent more than $1 million on market research to understand user frustrations with traditional test equipment. The information gleaned about soft-key-based oscilloscopes in particular was that they have simply become too difficult to use, because of their myriad features. Customers felt simple tasks should be simple to perform, advanced features should be easy to access, and help should be immediately available. The Infinium's GUI helps to deliver on all these requirements. Other test and measurement companies are also deploying Windows-95-based graphical interfaces in their test equipment.

Productivity gains are critical in today's environment of fast cycle times and multiplexed projects, where operating electronic test equipment is seen not as a valuable activity in itself, but rather merely a means to an end. As more users are exposed to GUI-based products and experience their benefits, expectations will rise further and manufacturers will introduce still newer advances. Features to look for in the future might include voice control, head-up displays, customized help, and integrated web browsers and servers. Graphical user interfaces, in some form, will likely be around for a while.

For more information, contact Jay Alexander, R&D Project Manager, Hewlett-Packard Electronic Measurements Division and the author of this article; 1900 Garden of the Gods Rd., Mail Stop ACIBR, Colorado Springs, CO 80907-3483; (719) 590-2476; fax (719) 590-3983; E-mail: jay_alexander@hp.com.

BRINGING Systems Together WITH Simulation

New tools help designers integrate power electronics, control, and mechanical systems.

Today's electrical system designers are turning to new, specialized computer modeling tools to mesh power, control, and mechanical systems into quick, seamless simulations. From utilities and transportation to motors and generators, designers have struggled to model systems in which electrical machinery and power electronics interact with mechanics and other systems. These new tools grew from the need to create simulations of an electrical system using electrical connections —the topology of the system—and controls, mechanics, and thermodynamics modeled with differential equations.

Recognizing that need, Hydro Quebec, the power authority in that part of Canada, developed the Power System Blockset for use with MATLAB and Simulink, the technical computing and simulation tools from The MathWorks, Inc. Blockset users can build a diagram of an electrical system with Simulink's "click-and-drag" approach. The resulting electrical schematic integrates with standard computer models for analysis in Simulink and MATLAB, allowing simulations to be built with less time spent on development and execution.

The value of this innovative approach is evident in a simple example of a circuit with an AC source and a load that is a resistor and an inductor. To model this system, Power System Blockset users can choose from among a collection of electrical system elements in the Blockset libraries. For example, the "Electrical Sources" area has the DC and AC voltage sources that are used to simulate the EMF for the circuit.

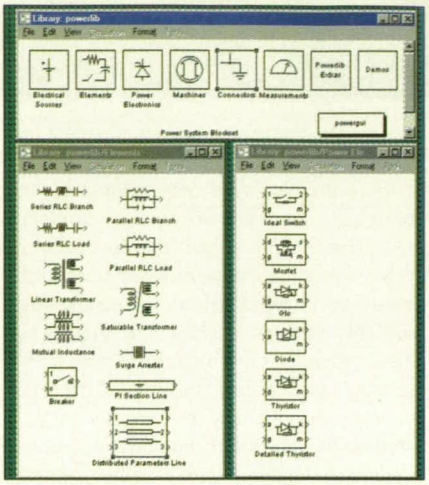
To create the model, the desired block is dragged into the drawing window. The load components are then found in the "Elements" set and added to the model. To keep the number of icons to a minimum, a single icon is used to create resistors, inductors, or capacitors either singly or in combination. Thus the load the designer wants to build is created from the series "RLC Branch" element. The inductor is set at 1 millihenry and the resistor to 10 ohms, while the capacitor is set to infinity, effectively eliminating it.

Simple connections are made by clicking and dragging a line from point to point. If multiple connections are needed, a set of "Connection" icons provides for grounds, bus bars, etc. A plot of the current appears in the "Scope" window. The "Current Measurement" block could be used at this point to bring in voltage or current, which could be used to add thermal capacity and thermal heating effects to the model. When the simulation starts, a plot in the "Scope" window begins, and the analyst can see the resulting current as a function of time. The simulation can be interpreted as it evolves, and parameter values, such as the supply voltage and supply frequency, can be changed, so the analyst can do "what if" and "off nominal" design tests.

Finding Fault

To test a new control and fault isolation approach on the DC side of the system, Hydro Quebec used the Power System Blockset to achieve a complex simulation with minimal effort on the designer's part. The Blockset also allowed Hydro Quebec engineers to integrate controller design with the simulation, keeping the physical system and the required response specifications clearly in view at all times.

Because the current in an AC system passes through zero at the frequency of the generator, a short-circuit fault in transmission lines can be easily cleared by a circuit breaker. When DC is used, however, the current never goes through zero, so clearing the fault is very difficult.



The Main Power System Blockset Library, along with the Elements and Power Electronics Libraries, demonstrate some of the blocks available to designers using this tool.

Typically, a DC circuit breaker needs to have a way to extinguish the arc created by the fault. But there is an alternative. By using rectifier feedback control to bring the current down toward the nominal current when the fault is detected, the rectifier can be shut down when the fault is clearly isolated. This approach is used in the Hydro Quebec system.

Most of the components of the simulation are blocks in the "Powerlib" library. The AC source is a 315-kilovolt generator that has a capacity of 5000 MVA. The block element used to model this source is a three-phase voltage source that resides in the "Extras" library of the Blockset. This voltage is stepped down to 210 kilovolts by a Y-Delta transformer, which provides the input to a 6-pulse thyristor bridge. The thyristor bridge is the most significant element in the overall DC transmission system, since it provides both control and rectification for the DC voltage. The output of the rectifier has an inductive load, represented by the series resistor and inductor. The voltage at the output of this load is passed to the transmission line, providing the connection to the inverter at the receiving end of the power.

Since we are investigating the effect of a fault at the connection between the load and the transmission line, the load is modeled as a simple back-EMF using a voltage-controlled source from the Blockset. The transmission line is a pi-section model that is a built-in block. The various built-in blocks used in this simulation have parameters that can be altered in a standard, intuitive way. The resistance, inductance, and capacitance per unit length are the first three entries, and the length of the line and the number of pi-sections used to simulate the line are the last two entries.

Continued on page 6a

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To simulate the short-circuit fault, a "Circuit-Breaker" model is used. The circuit breaker is modeled with the Blockset as a switch with inductance and resistance. It is turned on by a signal generated from a step function that goes from zero to 1 when time equals 0.1 second. This allows the simulation to get to steady state before the fault is applied.

Firing Order

In addition to the "Thyristor Rectifier" block, the library also contains the blocks that are required to fire the thyristors in the proper sequence based upon measurements of the phase of the three-phase AC power input to the rectifier. These blocks are the "Voltage Measurement" block and the "Synchronized 6-Pulse Generator."

The rectifier phase back angle (traditionally called alpha) for the rectifier is generated using a feedback controller modeled using Simulink. These blocks are included in a "DC Current Regulator" library.

The controller is a proportional plus integral controller with the gains set so that its output is the firing angle—alpha—in degrees relative to maximum voltage. Thus the controller will have an alpha of zero when the maximum voltage is commanded, 90 degrees when zero voltage is commanded, and 180 degrees when maximum negative voltage is commanded. The controller also contains a filter to clean up the current measurement, and it allows the current to be commanded through the input. All of the constants in this controller are in a per-unit system where the command of 1 pu gives a nominal DC current of 2.1 kiloamperes.

A set of harmonic filters is used to filter the commutation notches created by the rectifier on the AC line immediately after the generator. The Blockset contains these filters in the "320 Mvar" filter block.

The complete simulation models the fault and the way the current controller maintains the DC current at 1 pu despite the short circuit. In addition, when the fault is detected, assumed to be 0.2 second, the rectifier is commanded to shut off, so it is isolated from the short circuit.

The simulation captures the major features of the rectifier. The voltage, for example, is switching from phase to phase with the commutation of the thyristor going off from maximum current to zero before the new thyristor carries the full load current. The firing and commutation of the thyristors results in the typical voltage variation around the nominal that can be seen in the DC voltage plot. Also, when the short circuit occurs (at 0.1 second) the amplitude of the voltage swings increases because the rectifier is being commanded to a DC voltage that is close to zero in order to maintain the DC current at the desired 1 pu.

The controller shut-down of the rectifier at 0.2 second clears the fault current and results in both zero DC voltage and current being delivered to the load. This regulation of the current and subsequent clearing of the fault electronically is very desirable for high-power DC transmission, and was the major reason the simulation was built.

Helping BART

When power restrictions during peak traffic times left some of their trains in the San-Francisco-to-Oakland tunnel with less than adequate voltage, engineers at the Bay Area Rapid Transit (BART) system turned to the Power System Blockset in their search for a solution. BART uses DC rectifiers to provide power to the trains. Positive voltage is carried through a third rail, and the traction rails act as the return.

The DC electrical distribution system provides the power to the traction motors on the train. The train model must include a variety of mechanical effects, including the control system for the train's acceleration, the drive power electronics, such mechanical effects as air drag (both quadratic and linear), mechanical friction, gradient acceleration, and the initial position and velocity of the train, as well as the motor force and the motor back-EMF induced by the train's motion.

In the Simulink model of the train's motion, the acceleration is integrated to give the train speed, and the speed is integrated to give the train position. The train position is used to determine the resistance in the model from the train to the power supplies, so the model is nonlinear.

A further nonlinearity is the train air-drag term. The effective drag is a combination of constant drag terms, drag that is proportional to the velocity, and the actual air drag that is proportional to the velocity squared. These terms are developed in the model and appear at the summing junction just before the first integrator, with the acceleration being the output of this summation block.

Once the track model and the train model were developed in Simulink using the Power System Blockset, it was easy to model multiple trains. BART engineers bolstered the simulation model to include four trains on the tracks at various points east and west of the tunnel's midpoint.

The simulation using the four-train system model provided results that found their way into system improvements to keep the trains in the tunnel adequately powered even during peak travel. The scenario is further evidence that the ability to rapidly develop analysis models of electrical power systems can often mean the difference between a successful design and one that does not work.

For more information, contact Elizabeth G. Callanan, The MathWorks, 24 Prime Park Way, Natick, MA 01760; (508) 647-7417; fax (508) 647-7001; E-mail: liz@mathworks.com; http://www/mathworks.com.

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Improved Electron-Tunneling Magnetometer

A "planarized" design provides for improvements in fabrication and performance.

NASA's Jet Propulsion Laboratory, Pasadena, California

Efforts are underway to develop an electron-tunneling magnetometer with a "planarized" (as explained below) design. Older designs of electron-tunneling magnetometers are more three-dimensional in character and, as such, entail some difficulties of fabrication. [Such an older design was described in "Electron-Tunneling Magnetometer" (NPO-18493) *NASA Tech Briefs*, Vol. 17, No. 9 (September 1993), page 32.] Relative to the older designs, the present design offers advantages of sensitivity, manufacturability, and cost.

Like other tunneling-based microelectromechanical sensors, the developmental electron-tunneling magnetometer includes an electron-tunneling force/displacement transducer, wherein electrostatic-force feedback is used to counteract a force applied to a flexible cantilever or membrane by the phenomenon that one seeks to measure. The objective in the feedback scheme in any such sensor is to maintain, as closely as possible to a prescribed value, the small distance between (a) a stationary tunneling tip and (b) a counterelectrode on the cantilever or membrane. The electrostatic-deflection voltage applied to maintain the prescribed gap bears a known proportionality to the force applied to the transducer by the phenomenon that one seeks to measure. In the case of an electron-tunneling magnetometer, one seeks to measure a magnetic field through the Lorentz force that the field exerts on a known electric current in a coil of wire attached to the cantilever or membrane.

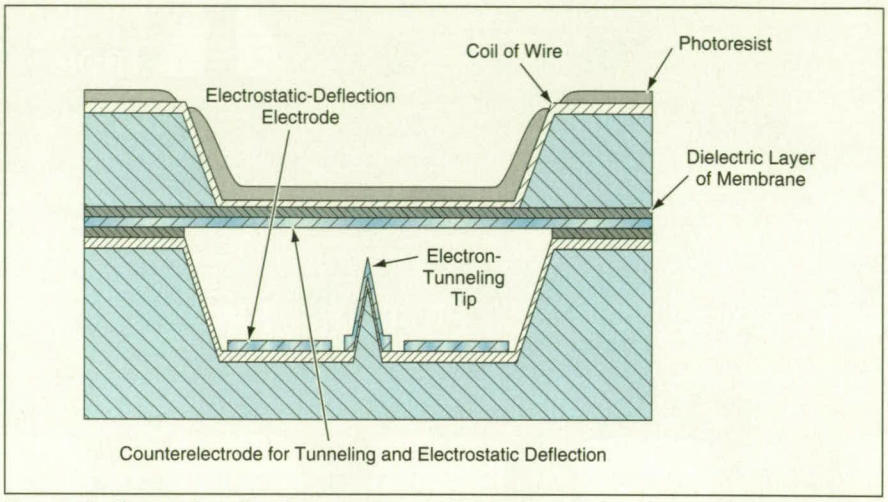

Figure 1. An **Electron-Tunneling Magnetometer of Older Design** is depicted here in a composite view of different stages of fabrication. Limitations on coil-line width arise from fabrication into the deep well.

A typical electron-tunneling magnetometer of older design is fabricated from two silicon wafers. One wafer is bulk-micromachined to form the tunneling tip in a base structure; the other wafer is bulk-micromachined to form a membrane about 0.5 μm thick, at the bottom of a well about 200 μm deep (see Figure 1). The wafers are then manually assembled (membrane wafer on top, tunneling-tip wafer below) and bonded together with epoxy. The difficulties associated with the older design arise principally in connection with fabrication of the coil of wire on the relatively thin membrane at the bottom of the relatively deep well. The fabrication difficulties lead to defects and thus to poor device yield and increased costs. In addition, the membrane-in-a-well configuration limits the achievable sensitivity.

In the present version, the design and fabrication of the lower wafer are substantially the same as in the older design. However, the design of the upper wafer is different, the method of bonding the wafers is different, and most of the fabrication of the membrane in the upper wafer is deferred until after the wafers have been bonded together (see Figure 2). Prior to bonding, the faying surfaces of the two wafers (the lower surface of the upper wafer and the upper surface of the lower wafer) are coated with gold. The gold coat on the lower surface of the upper wafer is destined to become the electrode layer on the membrane; a

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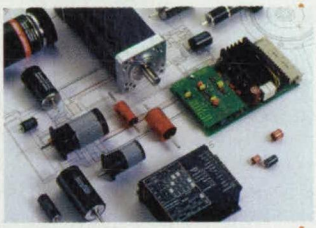
Our patented rhombic wound moving coil motors offer several advantages over conventional DC motors such as much longer brush life and extremely low electrical noise, low mechanical time constant for fast acceleration, low current consumption for extending battery life, no cogging for smooth rotation even at low speeds, and linear speed-torque constants for simple, accurate control.



Typical applications include air samplers, chart recorders, miniature pumps, chopper wheels, laser measuring devices, microscope stages, surgical devices, data storage devices, vision systems, and printers/labelers.

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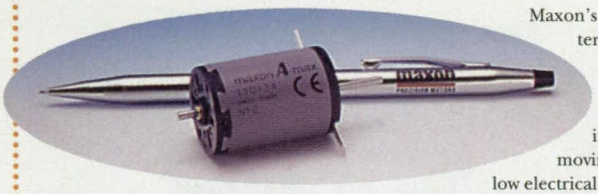

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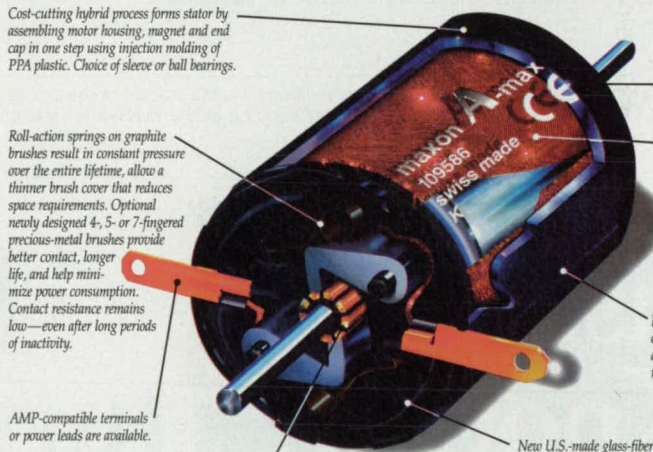

Cost-cutting hybrid process forms stator by assembling motor housing, magnet and end cap in one step using injection molding of PPA plastic. Choice of sleeve or ball bearings.

Elimination of a C-Clip groove results in higher torsional stability and greater cross-sectional strength.

Roll-action springs on graphite brushes result in constant pressure over the entire lifetime, allow a thinner brush cover that reduces space requirements. Optional newly designed 4-, 5- or 7-fingered precious-metal brushes provide better contact, longer life, and help minimize power consumption. Contact resistance remains low—even after long periods of inactivity.

Proven **maxon** *winding technique, enhanced by the latest winding technology, provides a high-performance relationship between the coil and magnet system.*

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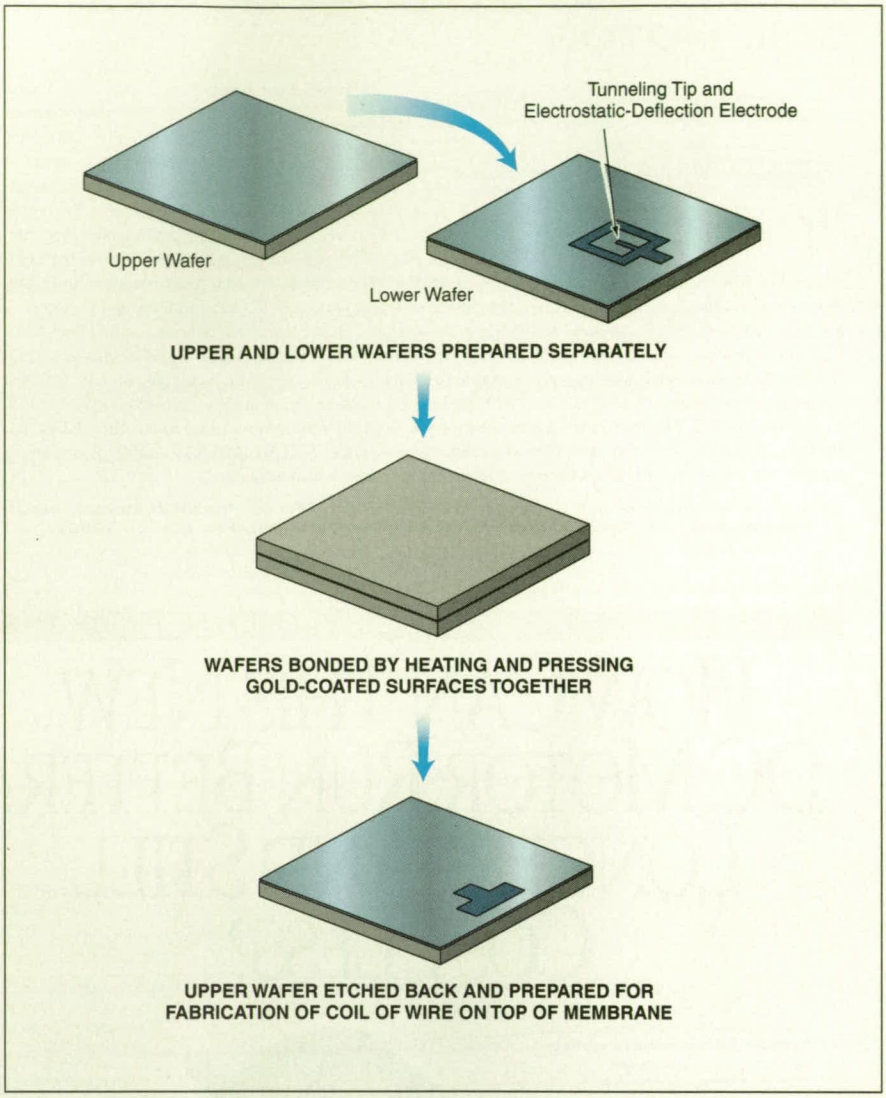

Figure 2. In the **Newer "Planarized" Design**, there is no well, and the fabrication of the coil of wire on the upper surface of the membrane is deferred until after bonding of the two wafers and etch-back of the upper wafer to the required membrane thickness.

window is formed in this coat to facilitate subsequent electrical contact with the tunneling tip and the lower electrostatic-deflection electrode.

The coated wafers are aligned, then bonded using a metal/metal thermocompression technique. Unlike in the older design, the membrane is not formed at the bottom of a well in the upper wafer. Instead, the entire upper surface of the upper wafer is etched back toward the gold layer to form the membrane, leaving a planar upper surface. Therefore, unlike in the older design, it is not necessary to manually align a recessed membrane on an upper wafer with a tunneling electrode on a lower wafer; as a result, manufacturability is enhanced and the cost of manufacture reduced. A fine coil of wire can be fabricated on top of the planar upper surface by use of conventional photoresist spin processing, more easily and with higher yield than in the case of a recessed membrane. The cost of manufacture is thus reduced further.

By enhancing manufacturability, yield, and robustness, the planarized design offers additional margin for optimization of design to increase sensitivity. As a result, the noise-floor is projected to reach 10 $nT/Hz^{1/2}$, as compared with about 7 $\mu T/Hz^{1/2}$ in the older design.

This work was done by Linda Miller, Judith Podosek, and Indrani Chakraborty of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category.*

Continued

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-20317, volume and number of this NASA Tech Briefs *issue, and the page number.*

Ferroelectric Electronic Scan Antennas

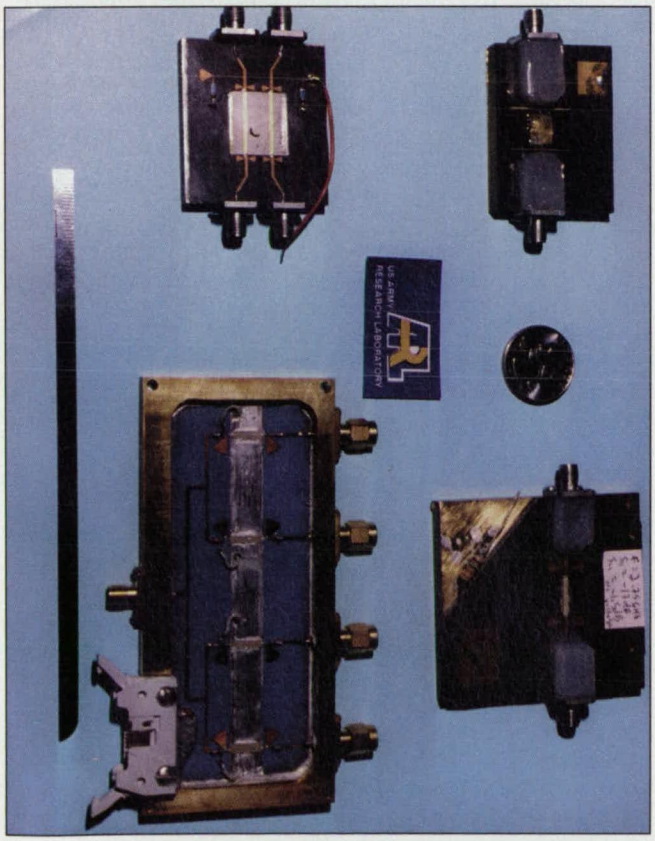
Ferroelectric phase shifters provide low-cost, high-performance electronic scan capability.

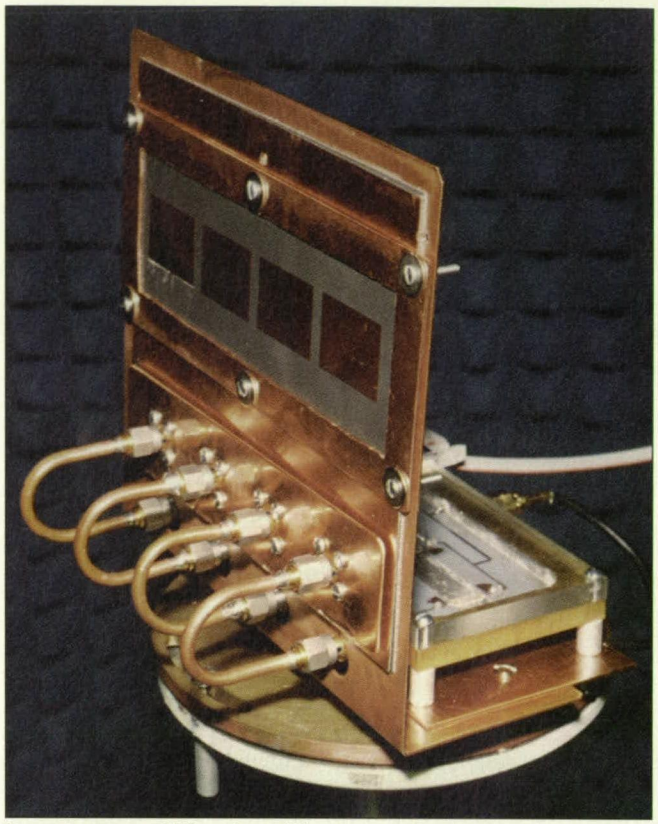
U.S. Army Research Laboratory, Adelphi, Maryland

Most current radar scanning antennas utilize mechanical scanning, relying on a gimbal, motor, and gear arrangements to physically rotate/elevate the antenna. This technique is slow, gravity-sensitive, and susceptible to shock and mechanical failure. High-speed multiple target tracking cannot be effectively done by this technique. Electronic scan, however, allows significantly faster scanning, requires no mechanical/physical rotation of the antenna, and lends itself to multiple-target tracking.

A great majority of current electronic scan antennas are controlled by ferrite phase shifters. These phase shifters

Ferroelectric (Paraelectric) Phase Shifters.





E-scan Antenna utilizing phase shifters.

exhibit low insertion loss and perform well, but their size and cost make them prohibitively expensive for most military and private-sector applications. The subject ferroelectric phase shifters are significantly lower in cost and smaller, and can also be electronically adjusted in real time for age and environmental stress. A large number of these ferroelectric phase shifters can be designed and placed on a single material substrate, thus further reducing the entire antenna size, weight, and cost.

This antenna employs advanced ferroelectric ceramic technology and computer-aided design with planar microwave circuitry. The microwave signal is impedance-matched into the ferroelectric phase shifter, and a DC voltage is applied across the ferroelectric element, allowing change/control of the dielectric constant of the ferroelectric material, thereby varying its electrical length. These ferroelectric phase shifters are installed in the corporate feed of a microstrip antenna array. By utilization of a microcontroller and voltage amplifiers, the antenna beam can be scanned by adjusting the voltage/phase shift of the various phase filters.

Scanning antennas find use for both military and private-sector applications. Ferroelectric scanning antennas would particularly find use where low cost is a requirement, such as in scanning antennas for pleasure boats, global positioning satellite applications, single-use battlefield weapon systems, etc. Other applications include airport radar scanning systems where high-speed scan is required for multiple aircraft detection, and battlefield scenarios where multiple-target tracking is needed.

This work was performed by Richard Babbitt, Thomas Koscica, and William Drach for the Sensors and Electron Devices Directorate (SEDD) of the **Army Research Laboratory**. *A patent has been obtained. This technology is available for licensing from the U.S. Army Research Laboratory. Inquiries with regard to this technology should be addressed to Ms. Norma Cammarata, ARL, 2800 Powder Mill Rd., AMSRL-CS-TT, Adelphi, MD 20783-1197; (301) 394-2952; fax: (301) 394-5818; E-mail: normac@arl.mil.*

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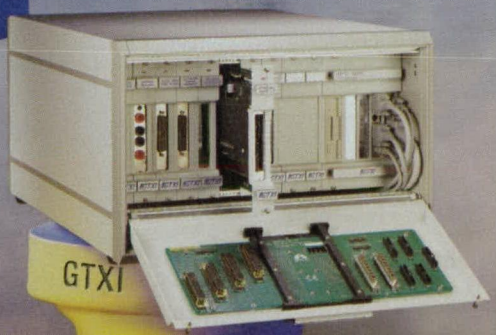

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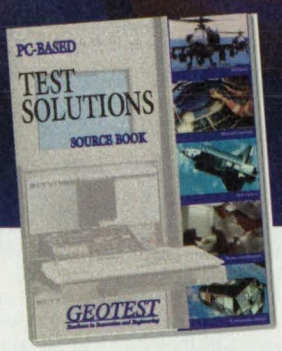

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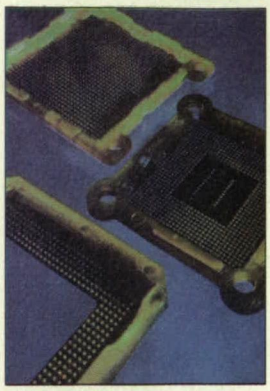


Metallized Particle Interconnections

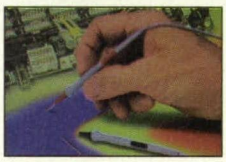
Thomas & Betts, Memphis, TN, announces the availability of products based on its patented metallized particle interconnect (MPI) technology that the company says provides a low-cost, high-speed thermally compensated direct socket solution consistent with BGA/LGA packaging for microprocessors with I/O counts from 400 to 5000. A flexible conductive polymer material with embedded metallized particles is formed into tiny microcolumns held in a grid pattern by a thin Kapton substrate that aligns with the I/O contacts of the packaged silicon device and the PC board's landing-pad contacts. When mechanically compressed by a frame holding the microprocessor and a heatsink, the particles in the columns join to form a conductive path. Virtually transparent to a 2-GHz signal with 100-ps rise time, the contacts exhibit no observable frequency-dependent effects at these speeds.

For More Information Circle No. 760

"Smart" Image Sensor

The Series 600 SmartImage CCD sensor for automated on-line inspection from DVT Corp., Norcross, GA, combines 640-x-480-pixel resolution with network communications capability for Ethernet and Fieldbus. With a footprint of 1.6 × 2.2 × 4 in., the Series 600 has an embedded Power PC processor, and can deliver control data such as quality-control inspection results, coordinate information for motion controllers, statistical process control data, and 2D code verification. Among useful tools in DVT's new software interface, FrameWork 1.4, are blob analysis, precision measure, motion control datalink, SPC datalink, and 2D code reader.

For More Information Circle No. 762



Precision Electronic Probe

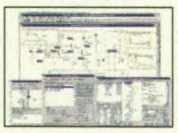
ITT Pomona Electronics, Pomona, CA, introduces the Precision Electronic Probe, a handheld probe for testing surface mount and densely populated circuit boards in repair and test-lab environments. The test socket is designed for use with a wide variety of tip points, including the spring-loaded plunger tip that provides a constant level of force on the probe tip. Its design is fully compliant with the IEC 1010 international safety standard, with Category III 1000-V overvoltage protection, and has a maximum current rating of 3 A. List price for a set of two with the Model 6275 stainless steel tip is $14.

For More Information Circle No. 763

High-Precision Operational Amplifier

The LMC2001 from National Semiconductor, Santa Clara, CA, is a 6-MHz rail-to-rail output operational amplifier that the company says offers unprecedented accuracy and stability at an affordable price and in a miniature package. The device uses patented techniques to measure and continually correct the input offset error voltage, thereby resulting in high stability over time and temperature, National says. The device exhibits no 1/f input voltage noise. Available in 5-pin SOT23 and 8-pin small-outline IC packages, the LMC2001 is priced at $1.20 in quantities of 1000.

For More Information Circle No. 766



Software for Analog/ Mixed-Signal Test

Intusoft, San Pedro, CA, releases Test Designer™ Version 8.5, an EDA tool that automates analog and mixed-signal test program development including fault diagnostics and isolation, failure mode effects analysis, and product acceptance test. Test Designer includes an integrated schematic entry tool, extensive model libraries, state-of-the-art SPICE3-based analog and mixed-signal simulator, a graphical data postprocessor, and many other features. List price of Test Designer, which is compatible with Windows 95 and NT, is $12,000; product maintenance is 15 percent of the purchase price.

For More Information Circle No. 769

Digitally Compensated Crystal Oscillator

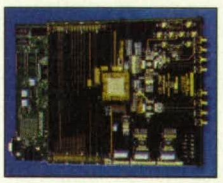
ValpeyFisher, Hopkinton, MA, announces a new digitally compensated crystal oscillator (DigiXO) that it says provides greater stability than conventional TCXOs currently available. Frequency stability of the DigiXO is similar to that of low-end oven-controlled crystal oscillators, with significantly lower power consumption, according to ValpeyFisher. The DigiXO exhibits stabilities of ±0.3 ppm over an industrial temperature range of -40 °C to +85 °C, the company says. Standard frequencies are available from stock. Price is $45-$60 in quantities of 1000, and delivery 8 weeks ARO.

For More Information Circle No. 765

Switching Power Supplies

Todd Products Corp., Brentwood, NY, offers the CPCI Series and DPCI Series 150-W and 350-W CompactPCI power supplies, the former for AC and the latter for DC input. The series offer two models with 150 W in 3U×8HP, and another two models at 350 W in 6U×8HP. The CPCI Series has universal AC input with PFC; the DPCI Series has 36- to 72-V DC input. They are hot-swappable power supplies for telecommunications and industrial computer systems that require redundancy and modularity. Both series are priced below $1 per watt in OEM quantities. Delivery is approximately 8 weeks ARO.

For More Information Circle No. 768



Chipsets for ATM/ SONET Building

Vitesse Semiconductor Corp., Camarillo, CA, introduces the V-FRAME 2.5 family of chipsets that contain all the data framing, multiplexing, and demultiplexing functions necessary to build a complete 2.5-Gb/s physical layer (PHY) for asynchronous transfer mode (ATM) and SONET/SDH communications equipment. The first chipset includes the VSC9110, a 2.5-Gb/s ATM UNI IC; the VSC8163, a 16:1 2.5-Gb/s multiplexer with integrated clock multiplication unit (CMU); and its companion chip, the VSC8164, a 1:16 2.5-Gb/s demultiplexer.

For More Information Circle No. 767

Schottky Barrier Diodes

Rohm Electronics USA, Nashville, TN, is marketing three new ultralow-forward-voltage Schottky barrier diodes that it calls suitable for use in portable computers, battery chargers, small power supplies, and similar equipment. They are available in 1-A, 3-A, and 5-A ratings. Typically the last (RB081L-20) operating with an average forward current of 1 A has a forward voltage of 0.29 V. The series is available in the very small PMDS surface-mount package (0.177 × 0.105 in.). Prices for 1500 or more are: for the RB161L-40 (1 A) $0.12 each; for the RB051L-40 (3 A) $0.23 each; for the RB081L-20 $0.34 each. Delivery is 12-14 weeks ARO.

For More Information Circle No. 770

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For More Information Circle No. 490

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Betatronix Custom Precision Potentiometers Catalog provides background on the company's industry-leading design and manufacturing capabilities. Betatronix has manufactured conductive plastic and wirewound potentiometers for 30 years. Catalog covers linear and rotary motion, aerospace and missile, outer space, and robotics and animatronics applications; full-color photos and mechanical parameters of all-inclusive product line are featured. Betatronix, Inc., 110 Nicon Court, Hauppauge, NY 11788; Tel: 516-582-6740; Fax: 516-582-6038; www.betatronix.com

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For More Information Circle No. 491

Estimating Attitude of a Robotic Balloon From Accelerations

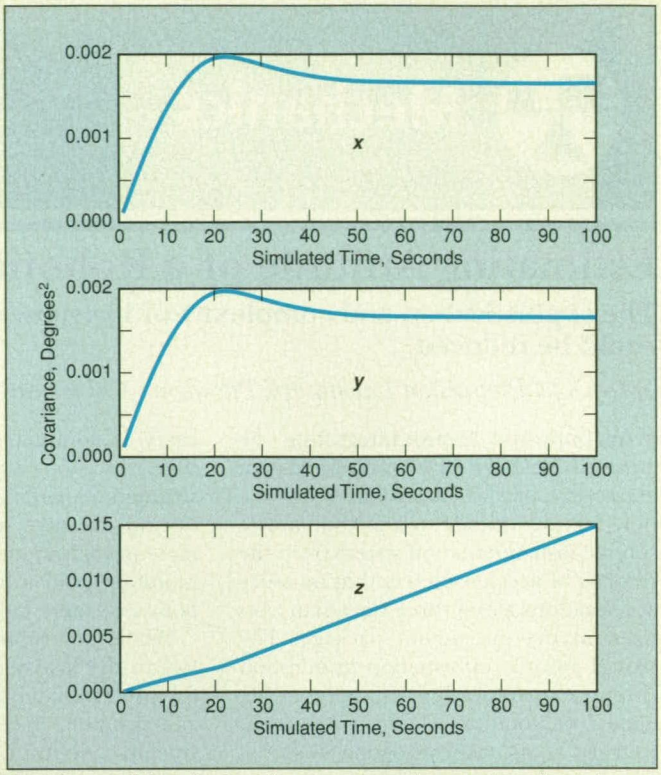
The sophistication and complexity of instrumentation needed to determine attitude could be reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved "sensor-integrating" algorithm has been developed for use in extracting partial information on the time-varying attitude of a balloon-borne robotic instrumentation system from the outputs of accelerometers that measure accelerations along three Cartesian axes fixed in the instrument package. The partial attitude information in question comprises two coordinates, representing angles of rotation of the instrument package about two orthogonal horizontal axes. If a single additional vector measurement (e.g., the direction to the Sun) is available, then all three angular coordinates are known; that is, the attitude is fully characterized. Because the algorithm could make it unnecessary to carry a complement of conventional high-precision attitude-measuring instrumentation, it affords potential for reducing the sizes, weights, and costs of meteorological, military, planetary exploration, and other balloon-borne robotic instrumentation systems.

While the outputs of the accelerometers in the instrument package are useful for estimating changes in velocity and position, they do not directly provide attitude information. However, the outputs the accelerometers contain indirect, partial information about the attitude of the instrument package in the following sense: Each accelerometer responds to the projection, onto its axis of sensitivity, of $\mathbf{a} - \mathbf{g}$, where $\mathbf{g}$ is the gravitational acceleration and $\mathbf{a}$ is the inertial acceleration. If one knows $|\mathbf{g}|$ and can estimate $\mathbf{a}$, then one can estimate the projections of $\mathbf{g}$ onto the accelerometer axes and, from these projections, deduce the orientation of the instrument package relative to the local vertical axis.

The key to estimating $\mathbf{a}$ lies in recognizing that the motion of the balloon-borne instrumentation system is dominated by swaying like that of a pendulum with damping plus random force and torque excitations from wind gusts. For the purpose of mathematically modeling the pendulum dynamics to estimate the state of the system (the state includes the angular coordinates that one seeks), the system is approximated as a rigid body



Covariances of Angular Coordinates representing rotations about the *x*, *y*, and *z* body axes evolved with time as a state-estimating mathematical model was applied in a test case. The boundedness of the *x* and *y* plots, as contrasted with the approximately linear rise of the *z* plot, demonstrates that it is possible to estimate two out of the three angular coordinates.

suspended below a pivot. Among the parameters of the dynamical model are the resonance frequencies of pendulum oscillations about the horizontal axes and the rates of damping of motions about all three axes. The resonance frequencies can be measured prior to flight. The rates of damping can be estimated and, even if not precise, help to ensure that, statistically, the pendulum oscillates about a vertical orientation and settles gradually to a vertical orientation when excitation is removed. The excitations from wind gusts are represented statistically, by use of first-order low-pass processes estimated from a wind power spectrum.

The dynamical model described above is converted to a nonlinear state-estimating model via an intermediate mathematical model that features a quaternion representation of attitude. The model integrates data from both accelerometers and simple gyroscopes to provide estimates of both position and attitude. The equations of the model are solved and state estimates updated by an algorithm that includes a continuous/discrete extended-Kalman-filter.

The model and algorithm were applied in a test case in which the dynamics of a balloon-borne system with representative parameters were simulated computationally. Among the results obtained in the test were covariances of the angular coordinates about the two horizontal (x and y) body axes and about the vertical (z) axis. As shown in the figure, the covariances for the x and y axes were found to be bounded (signifying that the angular coordinates in question can be known to within a specified accuracy), while the covariance for the z axis was found to increase approximately linearly with time (signifying that the estimate of the third angular coordinate deteriorates with time in the absence of further information).

This work was done by David Bayard, Robert Scheid, Donald Gennery, and Jayarao Balaram of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category. NPO-20315*

Swivel-Head Sampling Drill Bit

A hard material can be sampled at depth, without need for secondary actuators.

NASA's Jet Propulsion Laboratory, Pasadena, California

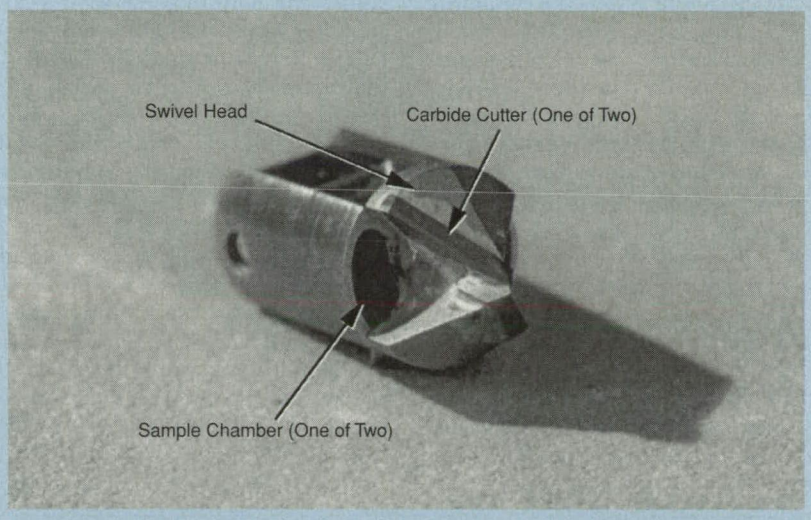
A swivel-head drill bit has been invented for use in acquiring a sample of a possibly hard material at a predetermined depth. This mechanism is a simpler and thus potentially cheaper alternative to deep-coring and sampling mechanisms that contain secondary actuators to open doors and/or to drive internal sampling features. The only actuator needed to operate the swivel-head drill bit is the drill motor.

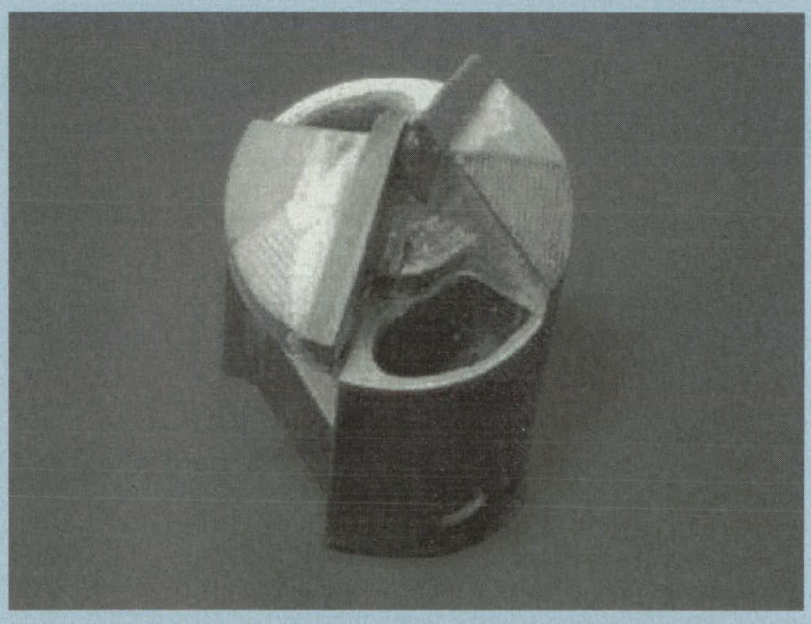
To be useful, a sampling mechanism must prevent mixing of sample material from the desired depth with material from other depths. Specifically, the present mechanism was developed subject to a requirement to limit mixing to a depth range of no more than 2 cm bracketing the desired depth. The challenge lay in satisfying this requirement without using secondary actuators.

The swivel-head drill bit includes (1) a body containing two identical sample chambers with openings at the front end capped by (2) the swivel head, which holds two cutters and can be rotated, relative to the body, to cover or uncover the openings. An integral shaft extends from behind the head through the body and is captured with a nut at the back end of the body. Small posts restrict the rotation of the head to a 90° range between the fully open and fully closed positions. The drill body and swivel head are made of MP35N alloy; the cutters are tungsten carbide inserts.

The head remains in the fully closed position as the drill bit is rotated clockwise during drilling. When the desired sampling depth has been reached, the bit is rotated counterclockwise, causing the head to swivel to the open position. The counterclockwise rotation is continued for a total of ten revolutions to move sample material into the sample chambers. Then the bit is rotated clockwise and pushed forward to swivel the head to the closed position. Finally, while rotating the bit clockwise slowly to keep the head in the closed position, the bit is withdrawn from the hole.

Swivel-head drill bits could be used to acquire subsurface samples from such diverse sources as geological sites, hazardous-waste dumps, structures, remote planets, comets, and asteroids. For example, they could be used to sample the walls and interiors of the Chernobyl nuclear reactors. In tests, the prototype swivel-head drill bit performed successfully in the acquisition of samples from the bottoms of holes in rock, plaster, and loose olivine sand.





The **Swivel Turns Freely** over a 90° range between two positions where it covers or does not cover, respectively, the chamber openings. The turning of the swivel head is actuated by rotation of the drill bit.

This work was done by Greg R. Gillis-Smith of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category. NPO-20390*

Illumination Device for Inspecting Window Surfaces

Small imperfections and dirt appear bright against a dark background.

John F. Kennedy Space Center, Florida

A special-purpose fiber-optic illumination device can be attached temporarily to a window to help an inspector examine window surfaces for scratches, pits, small-scale roughness, and dirt. This device was developed to replace an older fiber-optic illumination device that provided intense illumination to an area not much larger than the cross section of the fiber-optic light guide, had to be scanned manually over the entire window surface to complete an inspection, and often caused bright light to be reflected directly into the inspector's eyes during maneuvers ancillary to scanning. The present device illuminates a much larger area, does not shine bright light into the inspector's eyes, and leaves the inspector's hands free.

The basic illumination strategy is to launch the light into the window at an angle for which the light is totally internally reflected at smooth, flat, parallel window surfaces. Because of the total internal reflection, such surfaces appear dark when viewed from outside the window. However, surface imperfections scatter incident light, so that they appear bright when viewed from outside the window. Thus, small surface imperfections in a large area can readily be identified because they appear bright against a dark background.

The unique aspect of the present device lies in a fixture that aligns the output end of the fiber-optic light guide at the required angle and couples the light into the window (see figure). A transparent acrylic block holds the light guide at an angle of about 60° from the perpendicular to the surface of the window. The light emerges from the end of the light guide and travels through the block, through a thin interfacial layer of clear material, and into the window.

The interfacial layer can be made of clear rubber attached to the acrylic block by a clear glue. Alternatively, a liquid (e.g., water, an alcohol, an oil, or a glycerine compound) can be used as the interfacial material. In either case, it is necessary that the interfacial material fill the entire gap between the window and the block and have an index of refraction approximately equal to the indices of refraction of the acrylic and win-

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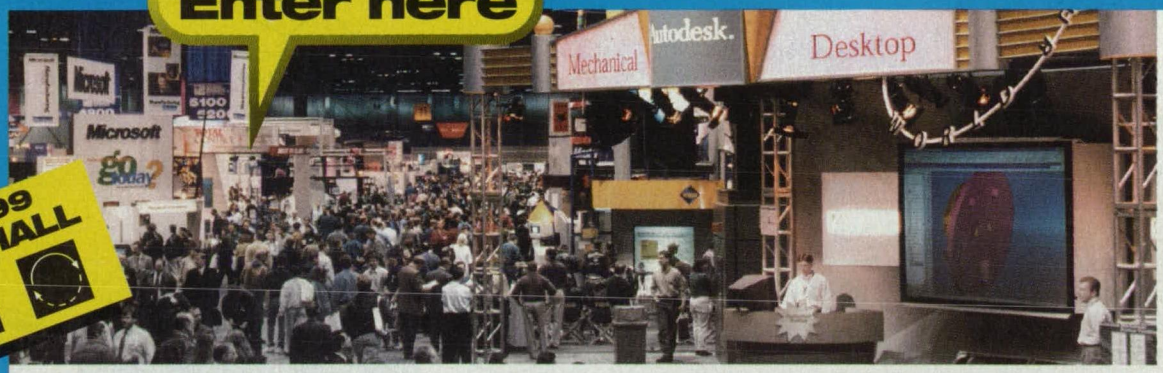

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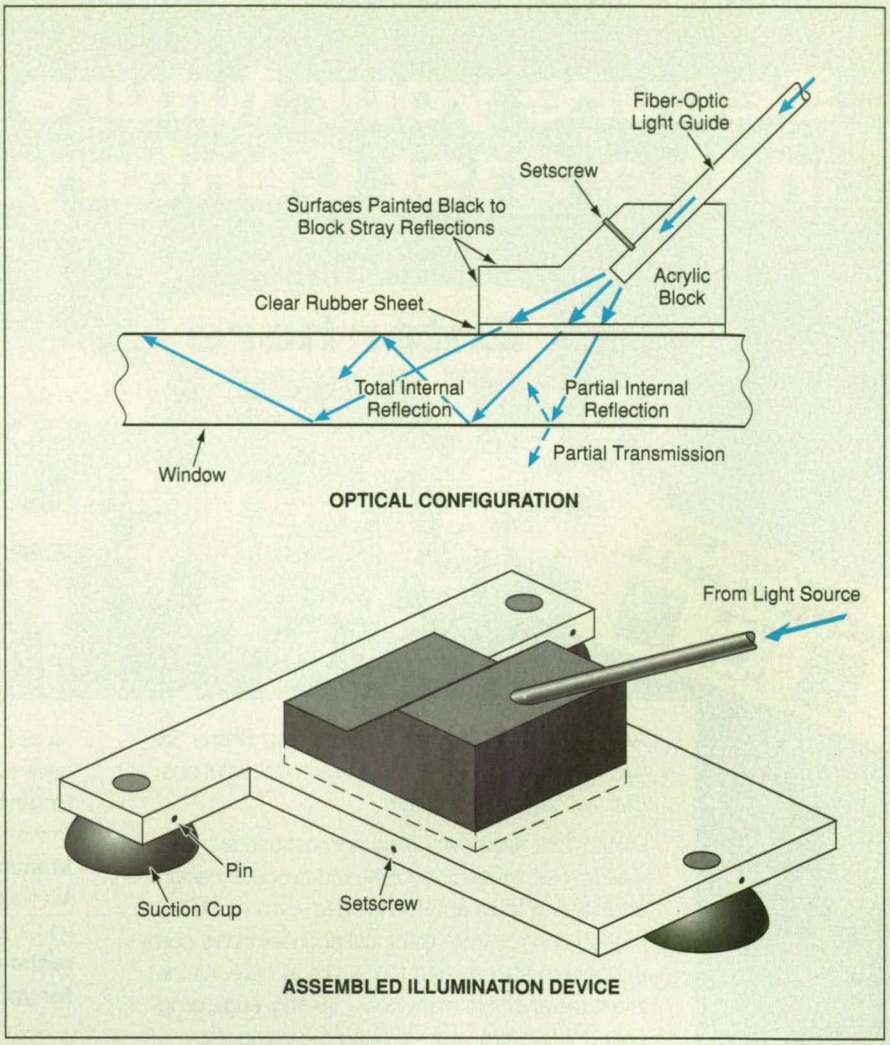

Light Is Launched Into the Window, predominantly at angles within the range of total internal reflection. The window surface as viewed from the outside therefore appears dark, except where scattering of light from surface imperfections disrupts total internal reflection, making the imperfections appear bright.

dow materials, to suppress reflections at the window/block interface.

The block is mounted in a frame that can be attached to the window by use of suction cups. The depth of mounting within the frame can be adjusted so that when the suction cups are pressed against the window, the clear rubber sheet is also pressed tightly against the window.

As an unavoidable consequence of the fan-out of light from the end of the fiber-optic light guide, some of this light travels at angles that are not within the range for total internal reflection. This portion of the light is partially reflected and partially transmitted at the window surface. In principle, one could incorporate a lens to reduce the fan-out, but in a typical case, the small increase in performance would not be worth the added complexity.

Because of small differences among the indices of refraction of the block, window, clear rubber, and glue, a small portion of the incident light is reflected from the interfacial region. This reflection could distract the inspector. Therefore, the exposed optical surfaces of the acrylic block are painted black to obscure the interfacial region from view.

This work was done by Barry Braden of **Kennedy Space Center,** *Robert C. Youngquist and Robert B. Cox formerly of I-NET, Inc., and Charles R. Floyd of United Space Alliance. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (407) 867-6373. Refer to KSC-11966.

Correction:
In the Physical Sciences section of the September issue, the name of the principal investigator for the brief entitled "Transparent Furnaces for High-Temperature Research" (LEW-16064, page 77) inadvertently was omitted. Dr. Stephen Bates of Thoughtventions Unlimited should have been noted as principal investigator, with David W. Yoel of Centorr/Vacuum Industries.

Books & Reports

Progress in Texturing by Use of Monatomic Oxygen

A report presents findings from recent research on the use of monatomic oxygen to form microscopic textures on the surfaces of polymers and extends the concept to some forms of carbon. Earlier developments in this field were described in two articles in *NASA Tech Briefs*, Vol. 20, No. 11 (November 1996); "Atomic-Oxygen Treatment To Obtain Non-Stick Polymer Surfaces" (LEW-15796) on page 44 and "Details of Atomic-Oxygen treatment of Polymer Surfaces" (LEW-15901) on page 95.

This work was done by Sharon K. Rutledge and Bruce A. Banks of **Lewis Research Center.** *To obtain a copy of the report, "Atomic Oxygen Texturing of Polymers and Carbons," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16604.

Collision-Avoidance Experiments on 7-DOF Robot Arms

A report describes experiments on the concept described in "Real-Time Collision Avoidance for a Robot Arm" (NPO-19861), *NASA Tech Briefs*, Vol. 20, No. 12 (December 1996), page 98. Under this concept, collision-avoidance software processes data computed by model-based obstacle-detection software to generate perturbations of the trajectory of a robot arm away from the commanded trajectory whenever the commanded trajectory brings the arm within a specified distance from one or more obstacle(s). In computing the perturbation, the software strives to nullify a virtual repulsive force proportional to the incursion of the obstacle plus a virtual damping force proportional to the closing velocity of the arm and the obstacle.

This work was done by Homayoun Seraji, Bruce Bon, and Robert Steele of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Experiments in Real-Time Collision Avoidance for Dexterous 7-DOF Arms," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*

NPO-20336

Update on System for Robot-Assisted Microsurgery

Two reports present updated information on a robotic system that extends the dexterity of a microsurgeon. The system was described in two articles in *NASA Tech Briefs*, Vol. 21, No. 10 (October 1997); namely, "Telerobot Control for Microsurgery" (NPO-19823), on page 46 and "Force-Feedback Device for Microsurgery" (NPO-19822), on page 86. To recapitulate, the surgeon manipulates a handle on a master robot arm, causing a slave robot arm to manipulate a surgical tool on a much finer scale, with hand tremor filtered out. The force of contact between the surgical tool and the patient's tissue is amplified and fed back to the surgeon's hand through the master robot arm.

This work was done by Curtis Boswell, Hari Das, Robert Steele, Timothy Ohm, and Edward Barlow of Caltech and Steve Charles of MicroDexterity Systems, Inc., for **NASA's Jet Propulsion Laboratory.** *To obtain copies of the reports, "Tool Actuation and Force Feedback on Robot Assisted Micro-Surgery System" and "Robot Assisted Micro-Surgery Development at JPL," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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JPL
Mail Stop 122-116
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Refer to NPO-20408, volume and number of this NASA Tech Briefs *issue, and the page number.*

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PORTABLE 10-COLOR, 10 OR 20 INPUT HYBRID BENCHTOP RECORDER

The OMEGA® DR130 Series portable hybrid recorder offers high speed scanning of 20 points/2 sec and high speed recording. This versatile recorder weighs less than 21 pounds (10 kg).

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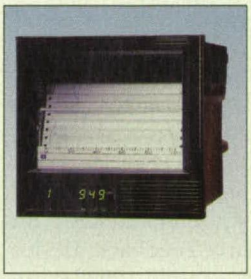

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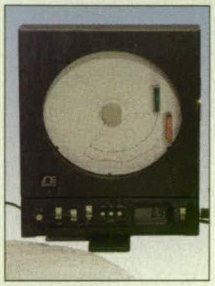

MICRO-PROCESSOR-BASED PH & TEMPERATURE RECORDER

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STICK-TYPE THERMOMETER

The HH63K Stick-Type handheld digital thermometer comes with a beaded Type K thermocouple. The HH63K offers data hold, max. readings, and function overload protection up to 24 Vac/Vdc, with a 0.3% accuracy.

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DIGITAL MULTIMETER

The HHM29 rugged multimeter measures temperature, AC/DC Volts, and AC/DC Amps. It is supplied with Type K thermocouple test leads and rubber boot. The HHM29 provides auto-hold, relative and relative set and auto power off to preserve battery life.

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INFRARED PYROMETER/ TRANSDUCER

The OS641F-MV-LS Stick Type infrared transducer offers portability and simplicity with one hand operation. The laser sighting marker is 1mW. The analog output is 1mV/°C/°F, emissivity is .95, and accuracy is ±3%.

Omega Engineering Inc.

For More Information Circle No. 605

INFRARED PYROMETER/ TRANSDUCER

The OS642F-LS infrared thermometer with laser sight has a thermopile detection element. Features include backlit LCD display, analog output 1mV/°C/°F, emissivity .95 and accuracy ±3%.

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Model CLH-II generates pulses and reads frequency. Converts any input into any output signal. Powers, reads and simulates digital sensors. Sources and reads millivolts, volts and milliamps. Powers, reads, and simulates 2-wire transmitters.

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MULTI-CALIBRATOR FOR PROCESS INSTRUMENTATION

The model CLD Multi-Calibrator for Process Instrumentation simulates and reads Ohms, RTD's and thermocouples. Sources and reads millivolts, volts and milliamps. Powers and reads 2-wire transmitters. Simulates 2-wire transmitters.

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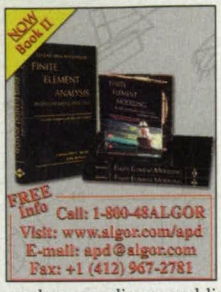

LATEST BOOK TEACHES NONLINEAR FEA & MECHANICAL EVENT SIMULATION

Linear and Nonlinear Finite Element Analysis in Engineering Practice explores nonlinear and linear theory. *Finite Element Modeling in Engineering Practice* is the industry standard for linear analysis. CD-ROM has search engine and color graphics. Address: 150 Beta Dr., Pittsburgh, PA 15238.

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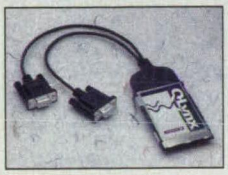

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Algor's Accupak/VE MES software replicates real-world behavior of a mechanical design having motion and impact. Accupak/VE gives stresses over time using known physical data, not assumed forces. Engineers can view events as they unfold. To see a replay of this car-suspension analysis and other analysis replays, visit Algor's home page or order your FREE CD-ROM. Tel: 412-967-2700; Fax: 412-967-2781; e-mail: info@algor.com; www.algor.com

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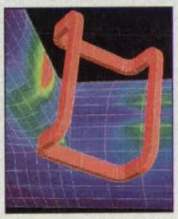

ELECTROMAGNETIC DESIGN & ANALYSIS SOFTWARE

OPERA Software provides user-friendly design and analysis tools for electrostatic, magnetostatic, and time-varying electromagnetic devices and systems. A wide frequency range (including resonant cavity calculations) and transient effects may be modeled. Particle beam modeling (including space charge effects) may be analyzed. Comprehensive user support is always provided. Vector Fields, Inc.; Tel: 630-851-1734; Fax: 630-851-2106; e-mail: info@vectorfields.com; www.vectorfields.com

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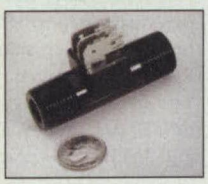
StacoSwitch offers Series 70 — a wide range of miniature switches that are resistant to wet, dusty, or oily conditions. The switches meet control and instrumentation requirements and come in a variety of display types, colors, and lighting styles. Options include: DPDT MOM or ALT; T-1 LED or incandescent MFB lamps; and drip/splash-proof seal. StacoSwitch; Tel: (714) 549-3014; Fax: (714) 549-0930; e-mail: mrktg@stacoswitch.com; www.stacoswitch.com

StacoSwitch
For More Information Circle No. 616



SMALL TURBINE FLOW SENSOR FOR APPLIANCES, DISPENSERS

Gems Sensors Inc. introduces the FT-110 TurboFlow Sensor. This in-line flow-monitoring unit measures only 2.2 inches long and is 0.7-inch wide. The FT-110 is accurate within ±3 percent of reading, with 0.5-percent repeatability in low-viscosity liquids with low flow rates from 0.1 to 8 GPM. Manufactured with FDA-approved materials, the FT-110 is ideal for dispensing systems in coffee, water, and soft-drink vending machines. Other applications include monitoring the cooling systems of medical lasers. Gems Sensors, Inc.; One Cowles Rd.; Plainville, CT; Tel: 1-800-847-5691; www.gemssensors.com

Gems Sensors, Inc.
For More Information Circle No. 619

New on the MARKET

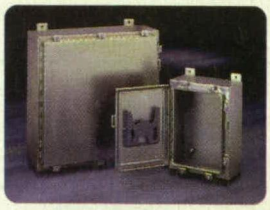
2D/3D Graphics Workstations

The TDZ® 2000 GXI ViZual Workstation, powered by up to two 400-MHz Intel Pentium II Xeon™ processors, is available from Intergraph Computer Systems, Huntsville, AL. The seven graphics options include Intergraph's Intense 3D™ RealiZm™ II 3D graphics, 2D graphics from Matrox, and entry-level 2D/3D graphics from AccelGraphics. The system features a tower chassis that houses seven full-length slots and five drive bays for expandability, with management tools, power management, and wake-on-LAN. Applications include traditional CAD, MCAD, animation, and visual simulation. **Circle No. 701**

Vibration Isolation Platform

Kinetic Systems, Boston, MA, has introduced a new version of the Series 9300 BaseMate vibration isolation platforms for heavy equipment requiring isolation from its surroundings. Applications include SEMs, TEMs, CMMs, steppers, aligners, and other floor-mounted equipment up to a gross load of 25,000 pounds. The platforms, available in four standard mount configurations, utilize a two-stage pendulum and airmount isolation system that provides omnidirectional control. The system's platform uses a 3-inch-thick, damped, rigid, epoxy-laminated sandwich of 1/2" steel top and bottom plates surrounding a 2-inch-thick, damped composite layer with a constrained layer damping system. **Circle No. 712**

Wall-Mount Enclosures



Industrial EMC wall-mount enclosures from Hoffman, Anoka, MN, are designed to protect electronic controls, instrumentation, components, and wiring. EMI/RFI shielding prevents electromagnetic interference from disrupting delicate instrumentation, microprocessors, or communications signals in industrial environments. Available in stainless steel or steel with zinc and yellow chromate plating, the enclosures range from 16 × 12 × 6" to 60 × 36 × 12". Features include a full-length hinged door and multiple screw clamps. Mild steel enclosures provide UL type 12 protection; stainless steel models are rated UL type 4x. **Circle No. 702**

Force-Feedback System

Virtual Technologies, Palo Alto, CA, offers the CyberGrasp™ whole-hand force feedback system, which provides realistic response when a user picks up or bumps an object in a virtual world. In order to replicate the resistance and firmness of digital objects, the system incorporates five actuators that provide proportional resistance to each finger. It can be used in various applications such as virtual prototyping, in which an engineer can feel parts snap together, or feel the resistance of parts that don't fit. It also is used in applications such as rehabilitation and training. **Circle No. 706**

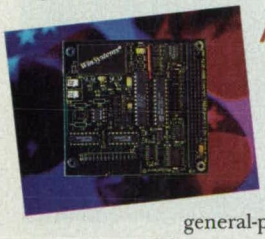
Plug-In Signal Conditioners

The 5B Series of analog signal conditioning modules from Analog Devices, Norwood, MA, are designed for PC-based data acquisition applications and support a variety of standard analog I/O ranges. The modules have ±0.05% accuracy and an operating temperature of -25 to +85°C. They feature 240V rms input protection, filtering, chopper stabilized low drift amplification, linearization for RTD and thermocouple inputs, and sensor excitation when required. The output module converts a 0 to -5V or -5V to an isolated 4-20 mA or 0-20 mA process current signal. Available options include 1-, 2-, 8-, and 16-channel backplanes and power supplies. **Circle No. 753**

Wireless Terminal

The CruisePAD NXT wireless Windows-based terminal from Cruise Technologies, Arlington Heights, IL, features an 800x600 resolution, 12.1" touchscreen; PC Card or microISA wireless LAN interfaces; connectivity via ICA or RDP to Windows terminal server; an embedded microphone and speaker; and an optional docking station and attachable embedded keyboard. The terminal enables mobile workers to access standard Windows, Windows NT, Java, and terminal emulation applications from anywhere via the handheld

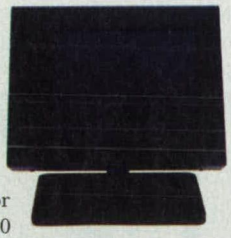
electronic tablet. Each user controls their own Windows session executing on the server, with only the video display transmitting to the mobile device. **Circle No. 713**



Analog-to-Digital Converter

WinSystems, Arlington, TX, has introduced the PCM-A/D16 successive approximation analog-to-digital converter. The 16-bit board is compatible with the PC/104-embedded PC bus, and is designed for industrial and instrumentation use with general-purpose data acquisition systems. It operates over a -40 to 85°C temperature range with no missing codes. Up to 16 single-ended or 8 differential input channels can be selected. The board supports two input ranges: 0 to +5 volts, and ±10 volts. Each input channel has overvoltage protection and can withstand continuous analog input voltages of ±30V. It is available with an onboard DC/DC converter. **Circle No. 707**

Daylight-Readable Monitor

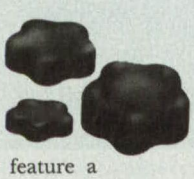


Earth Computer Technologies, San Clemente, CA, has introduced the EarthVue Mobile daylight-readable, color LCD monitor that plugs into any analog VGA output. The monitor runs on 12V and features a 500 nit, 8.4" active matrix display. A resistive touchscreen interface eliminates the need for keyboard or mouse operations. It measures 10 x 7.5 x 2.25" and is housed in a proprietary mobile enclosure. The monitor provides a wide viewing angle and features a universal ball joint mounting device for a range of installation options. **Circle No. 703**

Scan Converter

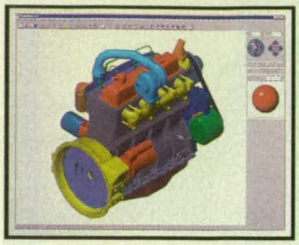
ZoomConverterHD high-resolution scan converter from PC Video Conversion, Morgan Hill, CA, accepts computer graphic (RGB) and NTSC/PAL television input signals and converts them to HDTV/ATV output. The converter automatically recognizes the input signal and performs resolution, frame rate, and aspect ratio conversion according to user-programmed parameters. Recognized signals include all PC resolutions from 640x480 to 1280x1024; workstation resolutions (Sun, SGI, HP, DEC/Compaq, IBM), and Macintosh resolutions. **Circle No. 710**

Fluted Knobs



Dimco-Gray, Centerville, OH, has introduced the DimcoGRIP™ soft-touch fluted knob with five lobes. Available in three sizes, they are used as clamping knobs in tight spaces, and are made with a hard thermoplastic center. They feature a 1-1/4" diameter hub, and can be molded with a variety of inserts, studs, bushings, or cored holes. The knobs can be customized in any color, including matching the color with any product's color scheme. They absorb shock, reduce vibration, and provide gripability, and can be used in cold, hot, dry, wet, and/or oily conditions. **Circle No. 715**

New on DISK



3D Visualization on PC

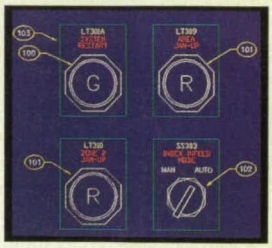
Solid Concepts, Valencia, CA, has introduced SolidView 3.2 3D mechanical design visualization software for Windows PCs. The software uses industry-standard STL and VRML files, which can be generated from most CAD systems, allowing users to view 3D designs regardless of their source. The new release features OpenGL graphics, which enables the use of more colors and advanced rendering features, such as transparency, to display complex parts and assemblies. **Circle No. 723**

Mechanical Engineering Tool

MSC/PATRAN Version 8 mechanical computer-aided engineering (MCAE) pre-and post-processing software is available from The MacNeal-Schwendler Corp., Los Angeles, CA. Enhancements such as rapid surface meshing have been added to facilitate the importing of CAD geometry. This capability allows engineers to rapidly mesh a CAD surface model with discontinuous complex surfaces, and reduces body modeling and meshing times. The software supports Unigraphics (UG) features and parameters, and allows direct access to ACIS geometry. Direct CATIA simplifies access to CATIA geometry. Applications include solving problems in automotive-body design, aircraft sections, and molded plastic parts. **Circle No. 722**

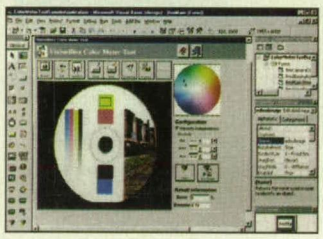
Wiring Diagram Program

CIMLOGIC, Nashua, NH, has released Toolbox/WD 14.6 for AutoCAD users that creates panel layout drawings using existing schematics, eliminating the manual transfer of information from the schematic drawing to the panel layout program. A new runtime database speeds up project-wide operations such as report generation, cross-referencing, and wire numbering. Using tools based on the Microsoft Access database format, Toolbox/WD builds and maintains the database, providing a real-time "snapshot" of key information carried in the AutoCAD drawing files. Other new functions include bill of materials, component list, nameplate reporting, smart item ballooning, and wire table generation. **Circle No. 717**



Color Tools for Machine Vision

Integral Vision, Farmington Hills, MI, has announced VisionBlox 3.0 machine-vision application development software, which features two new color tools for measuring, comparing, and filtering desired or unwanted colors in an image. The color meter tool is designed to compare colors against one another. The color filter enables the machine-vision system to filter various hues within an input image. The filter is programmed by selecting any number of colors to be filtered from a grabbed image. Applications include ink monitoring, print registration, and consistency in the printing industry and food quality control. **Circle No. 725**



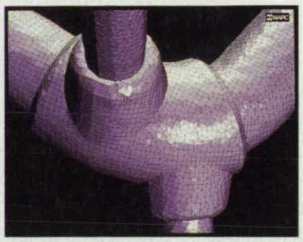
Engineering Analysis Tool

DesignSpace 4.0 engineering analysis software from ANSYS, Southpointe, PA, provides a CAE operating environment that is parametrically associative to multiple solid-modeling CAD systems. A new Solid Browser window enables design engineers to set up and review analyses produced from their solid models. Other enhancements include thermal-analysis capabilities and a Shape Wizard for topological optimization of solid-model designs. An Advanced Controls feature allows creation of templates that automatically produce advanced-analysis models from DesignSpace data. **Circle No. 718**

Real-World Simulation

CADSI® (Computer Aided Design Software, Inc.), Coralville, IA, has launched DADS version 9.0 mechanical system simulation software for UNIX and Windows NT platforms. It enables mechanical engineers to assemble, analyze, and animate real-world behavior of dynamic mechanical systems on their desktops. Results can be viewed as graphs and animation to evaluate product designs before building a physical prototype. Enhancements include expanded use of flexible bodies and faster solution algorithms for large-vehicle and aerospace applications. Other features include enhanced friction modeling, interactive simulation, and additional driver constraints. **Circle No. 721**

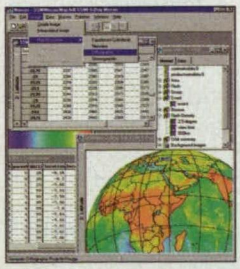
Metal-Forming Simulation



MARC/AutoForge 2.2 non-linear, finite-element software for simulating metal-forming processes is available from MARC Analysis Research Corp., Palo Alto, CA. It can automatically remesh entire 3D solid models as the analysis progresses through sequential stages of part deformation. Applications include simulating hot and cold bulk metal-forming processes such as forging, extrusion, rolling, and multi-stage forming. The software provides accurate data on forces and pressures at each stage of metal forming. Users can optimize processes to increase cycle times, minimize tool wear, avoid cyclic die overloading, and prevent cracking, overlapping, and incomplete die filling. CAD models can be imported from desktop systems such as AutoCAD and SolidEdge. It runs on Windows NT and UNIX platforms. **Circle No. 724**

Data Visualization Software

Advanced Visual Systems (AVS), Waltham, MA, has announced AVS/Express Version 4.0 data-visualization software that is a multi-platform (UNIX, Windows 95 and NT, and Internet/intranet), object-based software environment for visualizing complex data and building applications with interactive visualization and graphics functions. The program provides kits that contain reusable objects for data visualization, image processing, web interaction, and database connectivity. It uses an object-oriented visual programming interface to connect components to generate interactive 3D visualizations, as well as 2D plots and graphs. Enhancements include new Web-enabling features, expanded animation, and interfaces to Oracle 8 Spatial Cartridge and ESRI's Spatial Data Engine. **Circle No. 719**



Technical Data Analysis

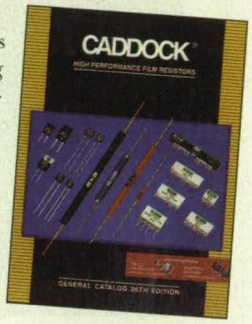
Noesys Visualization Pro from Fortner Software, Sterling, VA, is a desktop environment for managing scientific and technical data. It consists of four software applications: Noesys 1.3, Transform 3.4, T3D 1.1.3, and Plot 1.2. Noesys Visualization Pro organizes data into self-describing files including data sets, images, annotations, color palettes, and macros. Enhancements include visualization of global data sets to map projections, interactive resizing and rotating of images, new import options, and fast access to files containing multiple data sets. The software runs on Windows NT/95/98 and Power Macintosh. **Circle No. 726**

Machine-Vision Inspection

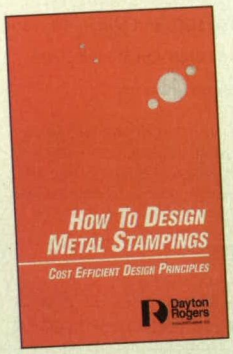
Cognex Corp., Natick, MA, has introduced PatInspect machine-vision software for detecting and classifying defects on objects. The software finds defects on objects even when the object has been rotated or its scale has been changed from the original, trained position. It also can detect flaws along the edges of an object. A rule-based defect "classifier" distinguishes between real defects and variations resulting from the manufacturing process. PatInspect runs on any Cognex Checkpoint 900 or MVS-8000 vision system. Applications include semiconductor manufacturing and inspecting print quality on packages and bottles. **Circle No. 716**

New LITERATURE

Film Resistors



Caddock Electronics, Riverside, CA, has introduced its 26th Edition General Catalog of high-performance film resistors and resistor network products. Featured items include Model MP725 D-Pak Style Power Film Resistors and Type CC Low Resistance Precision Chip Resistors. The catalog offers several models designed for use in harsh environments; other products are targeted for precision and ultra-precision instrumentation applications. **Circle No. 728**



Metal Stamping Design

Dayton Rogers, Minneapolis, MN, offers a 40-page booklet entitled, "How to Design Metal Stampings," which outlines the company's short-run metal-stamping operations. It serves as a selection guide to various processes, such as embossing, countersinking, and laser operations. Charts, graphs, and diagrams accompany the text, which also covers the advantages, limitations, and applications of each metal-stamping method. **Circle No. 729**

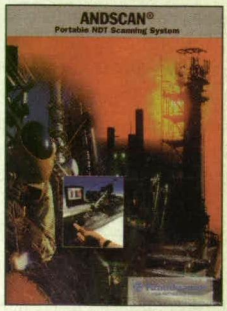
Instrument Selection Guide

Non-Linear Systems, San Diego, CA, has released a 24-page products catalog covering signal conditioning, transmitters, temperature and process digital panel meters, fuzzy logic controllers, and smart meters/counters. Product descriptions are accompanied by specifications, diagrams, color photographs, and a color-coded ordering guide. **Circle No. 732**

Precision Tools

Jonard Industries, Tuckahoe, NY, offers Catalog #2001, which describes precision tools, devices and instruments in seven categories. These include force gauges, telecommunication tools, tool kits, wire wrap tools, connector tools, burnishers, and alignment tools. Applications include telecom, computer, and electronic industries. **Circle No. 733**

Portable Scanning System



Krautkramer Branson, Lewiston, PA, offers a bulletin covering the ANDSCAN® portable scanning, data analysis, and documentation system for generation of inspection images. It is compatible with ultrasonic, eddy current, and bond-testing instruments. Its Windows-based software allows point-and-click parameter selection. Applications include checking carbon-fiber composite structures for impact damage and delamination. **Circle No. 735**

Harnessing Products

A Harnessing Products Catalog from Zippertubing, Los Angeles, CA, offers several product lines for cable bundling, harnessing, and protection. They include: Z-Wrap™ wrap-around jacketing; Z-Shrink™ heat-shrinkable tubing; ZipFlex™ braided expandable sleeving; SofTyz™ and Zip-Ty™ cable ties; and Laser Labels. **Circle No. 736**

Adhesive Products

Emerson & Cuming, Billerica, MA, has released the AMICON® and ECCOBOND® Adhesives Product Portfolio. These two product lines include general-purpose, electrically conductive, thermally conductive, surface mount, UV curable, high-strength, high-temperature, low-temperature, and fast-cure adhesives for plastics and elastomers, glass, ceramics, and specialty materials. **Circle No. 737**

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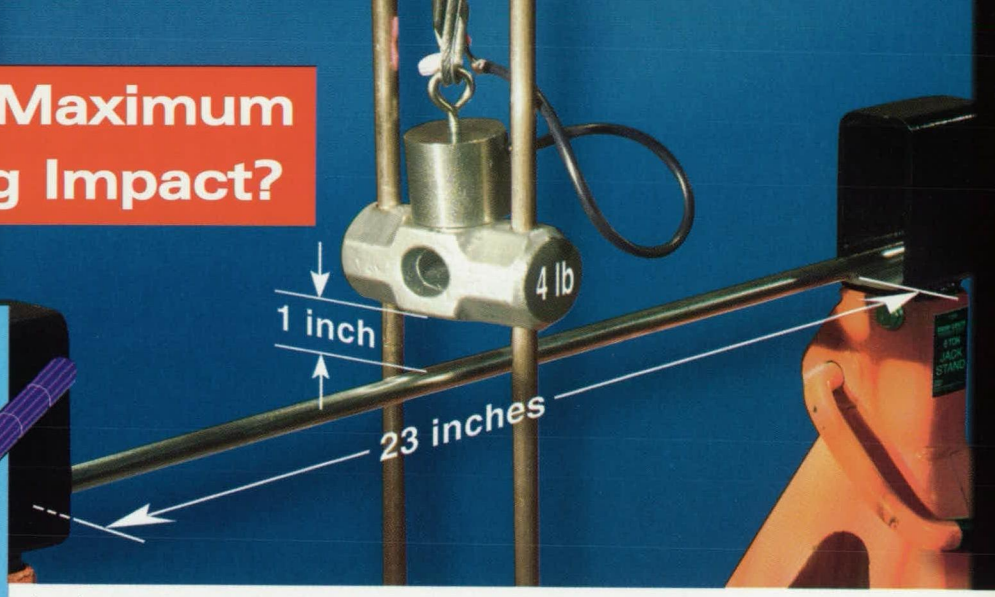
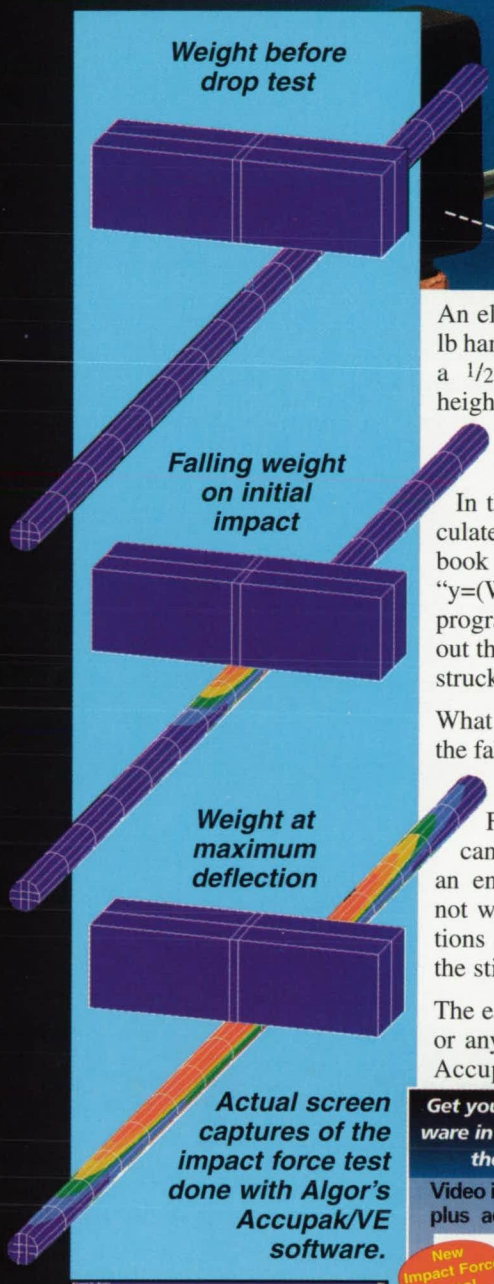
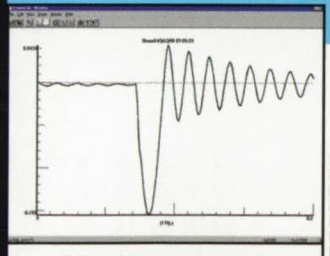
What is the Maximum Force During Impact?





Actual screen captures of the impact force test done with Algor's Accupak/VE software.



Monitor program showing bar deflection vs. time.

An electromagnet suddenly releases a 4-lb hammer head weight which drops onto a 1/2-inch diameter steel bar from a height of 1 inch as shown above. The bar is 23 inches long between the supports.

In the past engineers would try to calculate the maximum stress using handbook calculations such as "s=Mc/I" and "y=(WL3)/(48EI)" or a linear static FEA program — but they would have to figure out the force applied to the bar when it is struck by the falling weight.

What force would you think is caused by the falling weight? (The answer is upside down at the bottom of this page.)

For this simple situation, the force can be approximated by working out an energy balance. This approach will not work, however, for real-world situations due to the difficulty in calculating the stiffness.

The easy way to predict the result of this or any impact problem is to use Algor's Accupak/VE Mechanical Event Simulation software for Virtual Prototyping. Model the bar and hammer head weight with Superdraw III or your CAD system. Apply the dimensions and material properties in Accupak/VE and it will automatically run the virtual experiment and generate a replay showing the stresses and displacements at any or all instants during the time of the event.

Accupak/VE's Monitor virtual instrumentation program shows results graphically during run time. The Monitor program can show displacement, velocity, acceleration, frequency response, reaction forces and maximum stresses versus time as the event unfolds. Also available is an onboard FFT (Fast Fourier Transform) analyzer that converts displacement versus time into frequency versus energy so design engineers can see the energy absorption spectrum of the model during the event.

For more information on Accupak/VE for Mechanical Event Simulation, contact us or visit our web site at www.algor.com.

Answer: 56.6 lb